Final License Application
Volume II of III

Part 1 - Exhibit E

Lowell Hydroelectric Project

(FERC No. 2790)

April 30, 2021

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List of Acronyms

µS/cm	microsiemens per centimeter
ACHP	Advisory Council on Historic Preservation
ADA	Americans with Disabilities Act
APE	area of potential effects
ASRSC	Atlantic Sea Run Salmon Commission
AW	American Whitewater
BMI	Benthic macroinvertebrates
Boott	Boott Hydropower, LLC (or Licensee, or Applicant)
CEII	Critical Energy Infrastructure Information
CFPP	Comprehensive Fish Passage Plan
C.F.R.	Code of Federal Regulations
cfs	cubic feet per second
Chapter 91	M.G.L. Chapter 91 of the Waterways Act
CMR	Codes of Massachusetts Regulations
CSO	Combined Sewer Overflow
CSPA	Comprehensive Shoreland Protection Act
CWA	Clean Water Act
DDT	Dichlorodiphenyltrichloroethane
DLA	Draft License Application
DMMSPs	Dam Safety Surveillance and Monitoring Plan
DO	dissolved oxygen
EA	Environmental Assessment
EAP	Emergency Action Plan
E.L. Field	Eldred L. Field
EPT	Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies)
ESA	Endangered Species Act
FERC	Federal Energy Regulatory Commission (or Commission)
FGMP	Final General Management Plan
FHA	Federal Highway Administration
FLA	Final License Application

FPA	Federal Power Act
GECC	General Electric Credit Corporation
GIS	Geographic Information System
GPS	Global Positioning System
HAER	Historic American Engineering Record
ILP	Integrated Licensing Process
Integrated List	Integrated List of Waters
IPaC System	Information, Planning and Consultation System
IPANE	Invasive Plant Atlas of New England
ISR	Initial Study Report
kV	kilovolt
LHCDC	Lowell Historic Canal District Commission
LIHI	Low Impact Hydropower Institute
LMRLAC	Lower Merrimack River Local Advisory Committee
LNHP	Lowell National Historical Park
LRWU	Lowell Regional Water Utility
M	magnitude
MADCR	Massachusetts Department of Conservation and Recreation
MADEM	Massachusetts Department of Emergency Management
MADEP	Massachusetts Department of Environmental Protection
MADFW	Massachusetts Division of Fish and Wildlife
MADMF	Massachusetts Division of Marine Fisheries
Massachusetts NHESP	Massachusetts Natural Heritage Endangered Species Program
MassGIS	Massachusetts Bureau of Geographic Information
MDMR	Maine Department of Marine Resources
MDPW	Massachusetts Department of Public Works
MEOEEA	Massachusetts Executive Office of Energy and Environmental Affairs
MESA	Massachusetts Endangered Species Act
M.G.L.	Massachusetts General Law
mg/L	milligrams per liter
MHC	Massachusetts Historical Commission
MIPAG	Massachusetts Invasive Plant Advisory Group

MOU	Memorandum of Understanding
MRI	Merrimack River Initiative
MRTC	Merrimack River Technical Committee
MRWC	Merrimack River Watershed Council
MW	megawatt
MWh	megawatt hours
NAI	Normandeau Associates, Inc.
NEFMC	New England Fishery Management Council
New Hampshire NHB	New Hampshire Natural Heritage Bureau
NGOs	non-governmental organizations
NGVD 29	National Geodetic Vertical Datum 1929
NHDES	New Hampshire Department of Environmental Services
NHDFG	New Hampshire Department of Fish and Game
NHDHR	New Hampshire Division of Historical Resources
NHDNCR	New Hampshire Department of Natural and Cultural Resources
NHFGD	New Hampshire Fish and Game Department
NHL	National Historic Landmark
NHPA	National Historic Preservation Act of 1966
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NPS	National Park Service
NRHP	National Register of Historic Places
NRPC	Nashua Regional Planning Commission
NTU	Nephelometric Turbidity Unit
NWI	Nation Wetland Inventory
O&M	operations and maintenance
OSHA	Occupational Safety and Health Administration
PAD	Pre-Application Document
PM&E	protection, mitigation, and enhancement measures
Project	Lowell Hydroelectric Project

Proprietors	Proprietors of the Locks and Canals on the Merrimack River
PSP	Proposed Study Plan
Revised PPS	Revised Process Plan and Schedule and Determination on Requests for Study Modifications for the Lowell Hydroelectric Project
RM	river mile
RMC	RMC Environmental Services
ROR	run-of-river
RSA	Revised Statutes Annotated
RSP	Revised Study Plan
RTE	rare, threatened, and endangered
SAV	submerged aquatic vegetation
SCORP	Statewide Comprehensive Outdoor Recreation Plan
SDR	Supporting Design Report
SD1	Scoping Document 1
SD2	Scoping Document 2
Section 106	Section 106 of the NHPA
SPD	Study Plan Determination
SHPO	State Historic Preservation Officer
stakeholders	resource agencies, federally recognized Indian tribes, non-governmental organizations (NGOs), and other interested parties
SWQS	surface water quality standards
Merrimack River Technical Committee	Representatives from NHDFG, MADFW, USFWS, USFS, NMFS
THPO	Tribal Historic Preservation Officers
TMDL	total maximum daily loads
TBSA	turbine blade strike analysis
USACE	U.S. Army Corps of Engineers
USC	United States Code
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

VP	vegetation points
WPA	Wetlands Protection Act
WQC	Water Quality Certification
WUA	Weighted Useable Area
YOY	Young-of-year

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Exhibit E Environmental Report (18 C.F.R. § 5.18)

E.1 Introduction

Boott Hydropower, LLC (Boott or Licensee) is the Licensee, owner, and operator of the 20.16-megawatt (MW) Lowell Hydroelectric Project (Project or Lowell Project) (FERC No. 2790). Boott operates and maintains the Project under a license from the Federal Energy Regulatory Commission (FERC or Commission). The Commission, under the authority of the Federal Power Act (FPA), 16 United States Code (USC) §791(a), et seq., may issue a license for up to 50 years for the construction, operation, and maintenance of non-federal hydroelectric developments. The existing license was issued by FERC on April 13, 1983 and expires on April 30, 2023. Boott is pursuing a new license for the Project using the Commission's Integrated Licensing Process (ILP) as defined in 18 Code of Federal Regulations (C.F.R.) Part 5.

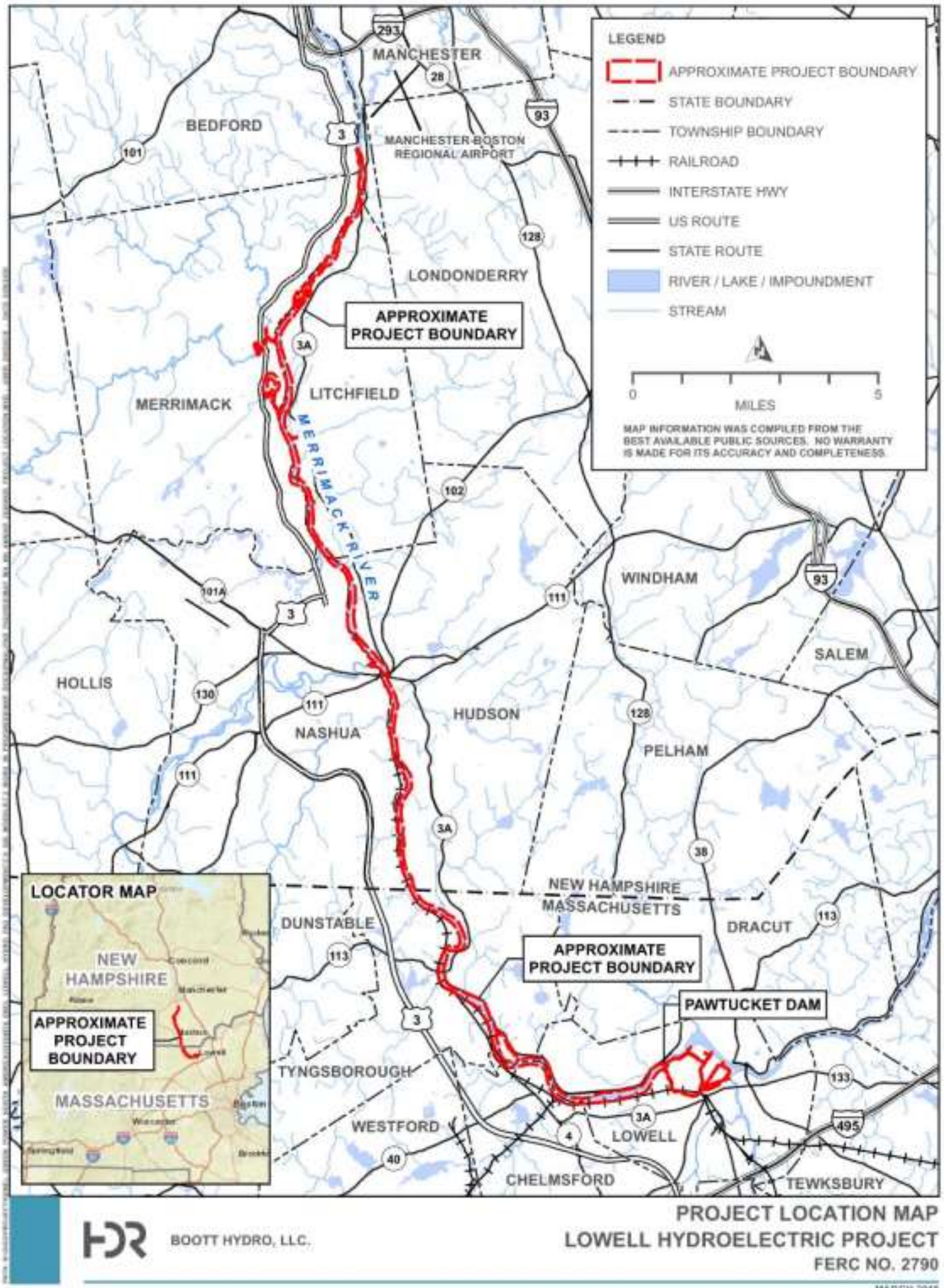
In accordance with the ILP and applicable regulations at 18 C.F.R. § 16.9(b), Boott must file its final application for a new license (Final License Application or FLA) with the Commission no later than April 30, 2021.

The Lowell Project is located at river mile (RM) 41 on the Merrimack River in the City of Lowell in Middlesex County, Massachusetts, with the current impoundment extending approximately 23 miles upstream into Hillsborough County, New Hampshire (Figure E.1-1).

The existing Lowell Project consists of:

1) A 1,093-foot-long, 15-foot-high masonry gravity dam (Pawtucket Dam) that includes a 982.5-foot-long spillway with a crest elevation of 87.2 feet National Geodetic Vertical Datum 1929 (NGVD 29) topped by 5-foot-high pneumatically-operated crest gates deployed in five independently-operable zones;
2) A 720-acre impoundment with a normal maximum water surface elevation of 92.2 feet NGVD 29;
3) A 5.5-mile-long canal system which includes several small dams and gatehouses;
4) A powerhouse (Eldred L. Field) which uses water from the Northern Canal and contains two turbine-generator units with a total installed capacity of 15.0 megawatts (MW);
5) A 440-foot-long tailrace channel;
6) Four powerhouses (Assets, Bridge Street, Hamilton, and John Street) housed in 19^{th} century mill buildings along the Northern and Pawtucket Canal systems containing 15 turbine-generator units with a total installed capacity of approximately 5.1 MW;
7) A 4.5 mile-long, 13.8-kilovolt transmission line connecting the powerhouses to the regional distribution grid;
8) Upstream and downstream fish passage facilities including a fish elevator and downstream fish bypass at the Eldred. L. Field (E.L. Field) powerhouse, and a vertical-slot fish ladder at the Pawtucket Dam; and
9) Appurtenant facilities.

Figure E.1-1. Lowell Project Location and Existing Boundary Map



Boott proposes to eliminate the four mill powerhouses and associated canals from the new FERC license. The project features proposed to be retained in the new license include: the Pawtucket Dam; the E.L. Field powerhouse; the section of the Northern Canal and associated structures leading from the Pawtucket Dam to the E.L. Field powerhouse; the Hydro Locks; all fish passage facilities; and the Guard Lock and Gates facility. Boott will continue to manage the canal structures, water levels and flows using best practices and consistent with current agreements with the National Park Service (NPS) and other stakeholders.

At the normal pond elevation of 92.2 feet NGVD 29 (crest of the pneumatic flashboards), the surface area of the impoundment encompasses an area of approximately 720[1] acres. The gross storage capacity between the normal surface elevation of 92.2 feet NGVD 29 and the minimum pond level of 87.2 feet NGVD 29 (spillway crest) is approximately 3,600[2] acre-feet. The Project operates in a run of river (ROR) mode using automatic pond level control of the E.L. Field units and has no usable storage capacity.

The Project's primary features are located along the Merrimack River in the City of Lowell, Massachusetts. The City of Lowell was founded in the early 1820s by Boston merchant capitalists and became one of the most significant planned industrial cities in America (Hay 1991). Lowell's factory system, which used the waterpower of the Merrimack River, incorporated new technologies to provide for the mass production of cotton cloth in mills throughout the city (NPS 1981). Lowell established the pattern for large-scale waterpower development for the next 50 years (Hay 1991).

Several Project facilities are located within overlapping locally, state, and nationally designated parks and historic properties and preservation districts. The Project's Pawtucket Dam and E.L. Field Powerhouse are located along the mainstem of the Merrimack River. The Project's existing two-tiered network of man-made canals extends throughout downtown Lowell. The 5.5-mile-long canal system provides flow to the Project's existing Hamilton, Assets, Bridge Street, and John Street developments. The Hamilton, Assets, Bridge Street, and John Street power stations and turbines are housed in large former mill buildings. The mill buildings are not included in the existing Project; the Project Boundary includes only the turbines and associated waterways and equipment at these downtown mill sites. In addition to the Pawtucket Dam and hydroelectric developments, the existing Project also includes miscellaneous civil works in the City of Lowell, including the Guard Lock and Gates, Moody Street Feeder Gatehouse, Lawrence Dam, Hall Street Dam, Tremont Wasteway, Lower Locks and Dam, Swamp Locks and Dam, Merrimack Dam and Merrimack Gate, Rolling Dam, and the Boott Dam.

The canal system, the downtown mill sites, and many of the Project's existing civil works, are contributing resources to Lowell Locks and Canals National Historic Landmark (NHL) District. The canal system and many Project facilities are also located within the Lowell National Historical Park (LNHP) managed by the NPS and the larger Lowell Historic

[1] During the initial licensing, the Project impoundment surface area was estimated at 720 acres. As a part of this relicensing, Boott updated Exhibit G and generated a new surface area estimate of 1,236 acres. See Exhibit G.

[2] The Project impoundment has an estimated gross storage capacity of 6,180 acre-feet.

Preservation District. The LNHP was established by Congress in 1978 to “preserve and interpret the nationally significant historical and cultural sites, structures, and districts in Lowell, Massachusetts, for the benefit and inspiration of present and future generations.” The park is by design a partnership park in which federal, state, and local governments as well as the private sector and local community carry out the legislative intent of the park unit. The Lowell National Historical Park is also listed on the National Register of Historic Places (NRHP), and certain properties within the park overlap with properties in the NHL District.

The Lowell Heritage State Park, established in 1974 as a precursor to the LNHP, is also located within the City of Lowell and is comprised of linear greenways along the Merrimack River and canal system and a collection of historic buildings and structures related to the industrial development of the city. These buildings and structures include Project features and properties located within the NHL District. The Lowell Heritage State Park is operated by the Massachusetts Department of Conservation and Recreation (MADCR) and features exhibits created in partnership with the NPS (MADCR 2018). With the exception of the Rynne Bathhouse, all of the built resources within the Lowell Heritage State Park fall within the Lowell Historic District, designated by the City of Lowell to “…ensure that development activities within the district are consistent with the preservation of its 19th century setting” (MADCR 2014). Portions of the Lowell Heritage State Park also overlap with the Lowell Locks and Canals NHL District and the LNHP.

In accordance with 18 C.F.R. § 5.16(a), Boott filed the Draft License Application (DLA) with the Commission on December 2, 2020. FERC and stakeholders had 90 days to provide comments on the DLA (i.e., until March 2, 2021). Comments on the DLA were filed by the following participants: AW, Lowell Plan, Inc., City of Lowell, Massachusetts Department of Conservation and Recreation (MADCR), Lowell Parks & Conservation, Greater Lowell Community Foundation, NPS, United States Fish and Wildlife Service (USFWS), Massachusetts Senator Edward Kennedy, Lowell Historic Board, Massachusetts Historical Commission, and the University of Massachusetts. Boott has reviewed and considered all comments received, as evidenced through further development of the Licensee’s measures proposed in this Final License Application.

The purpose of the Exhibit E, as defined in 18 CFR §5.18, is to describe: (1) the existing and proposed Project facilities, including Project lands and waters; (2) the existing and proposed Project operation and maintenance, to include measures for protection, mitigation, and enhancement (PM&E) with respect to each resource affected by the Project proposal; and (3) the continuing impacts of existing Project operations and maintenance on resources, including direct, indirect, and cumulative impacts based on information generated during the relicensing studies. Exhibit E of this license application was prepared consistent with 18 C.F.R. § 5.18(b) and is intended to support FERC’s required analysis under the National Environmental Policy Act of 1969 (NEPA)[3], as amended. The analysis of potential effects is based on the information presented in Boott’s April 30, 2018 Pre-Application Document (PAD), consultation with stakeholders, the results of eleven completed studies and two on-going studies, pursuant to the

[3] 42 U.S.C. § 4321, et seq.

Commission's Study Plan Determination (SPD), and other information obtained by the Licensee. Table E.1-1 summarizes the studies conducted or to be completed by Boott.

Table E.1-1. Lowell Hydroelectric Project Study Reports

Study Report	Filing Type	Filing Date
Downstream American Eel Passage Assessment (Updated Study Report [USR])	Public	February 25, 2021
Juvenile Alosine Downstream Passage Assessment (USR)	Public	February 25, 2021
Upstream and Downstream Adult Alosine Passage Assessment (USR)	Public	February 25, 2021
Fish Passage Survival Study (Initial Study Report [ISR])	Public	February 25, 2021
Three-Dimensional Computational Fluid Dynamics (CFD) Modeling	Public	May 2021 (Anticipated)
Instream Flow Habitat Assessment and Zone of Passage Study in the Bypassed Reach (ISR)	Public	February 25, 2021
Fish Assemblage Study (USR)	Public	February 25, 2021
Recreation and Aesthetics Study (USR)	Public	February 25, 2021
Resources, Ownership, Boundaries, and Land Rights Study (ISR)	Public	February 25, 2021
Water Level and Flow Effects on Historic Resources Study (ISR)	Public/Privileged	March 5, 2021
Operation Analysis of the Lowell Canal Study (ISR)	Public	February 25, 2021
Historically Significant Waterpower Equipment Study (ISR)	Public	February 25, 2021
Whitewater Boating and Access Study	Public	June 2021 (Anticipated)

On February 25, 2021, Boott filed the ISR studies and USR studies noted above. Boott held a Revised ISR Meeting to discuss the results of these studies on March 11, 2021. Pursuant to the ILP, Boott filed a Revised ISR Meeting Summary with the Commission on March 26, 2021. Stakeholders were provided a 30-day period (ending on April 25, 2021) to provide comments on the Revised ISR Meeting Summary, recommend study modifications, or propose new studies. By letters to the Commission, National Marine Fisheries Service (NMFS), Massachusetts Division of Fisheries and Wildlife (MADFW), USFWS provided comments on the February 2021 Revised ISR and Revised ISR Summary.

The following sections summarize the existing environmental setting of the Project and the baseline conditions under which this environmental assessment is being undertaken.

E.2 General Description of the River Basin (18 C.F.R. § 5.18 (b)(1))

E.2.1 Drainage Area and Length of River

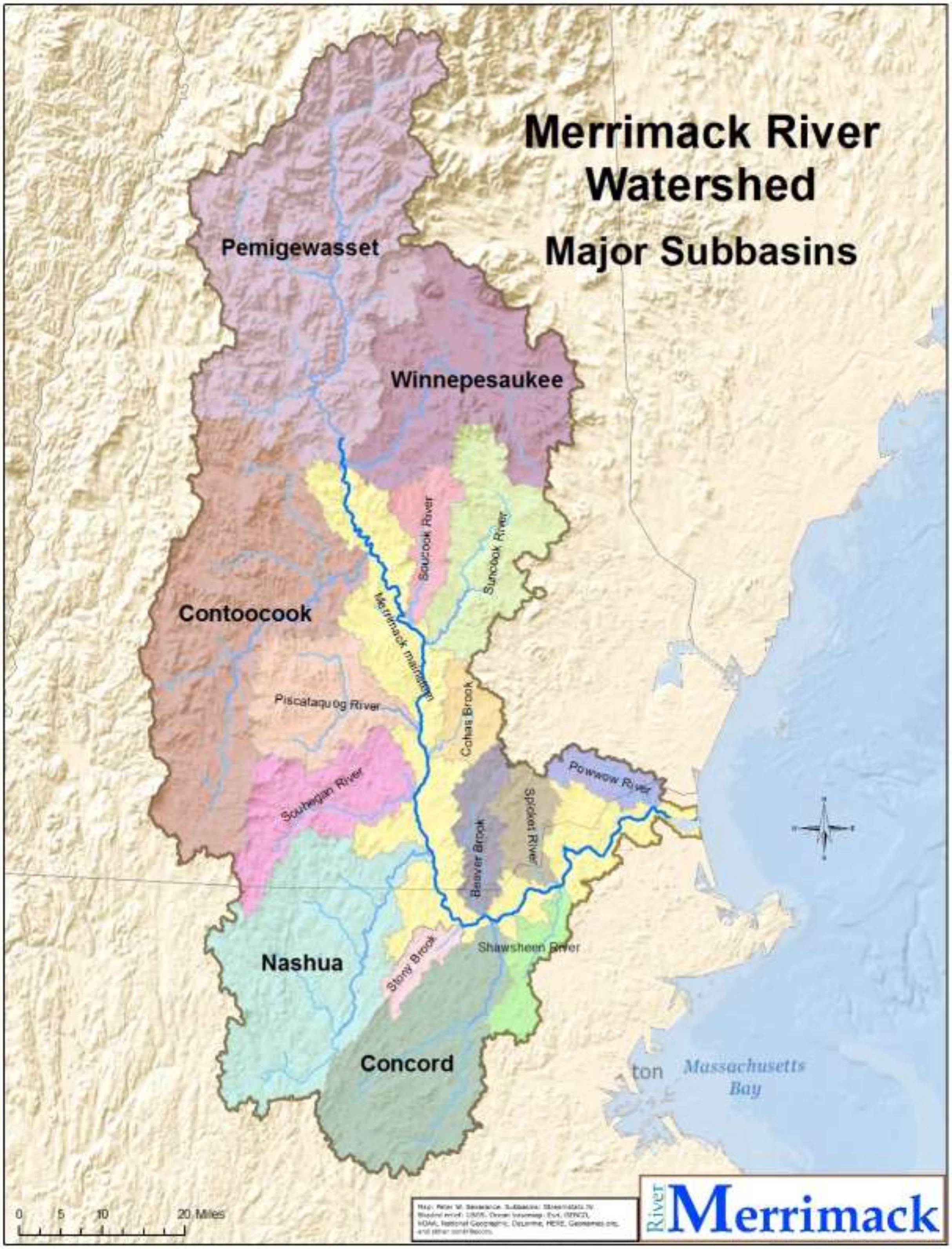
The 116-mile-long Merrimack River originates near Franklin, New Hampshire at the confluence of the Pemigewasset and Winnipesaukee Rivers (USACE 2003). The river flows southward for approximately 78 miles in New Hampshire, turns abruptly at the New Hampshire-Massachusetts boarder, and flows in a northeasterly direction for approximately 40 miles before draining into the Atlantic Ocean near Newburyport, Massachusetts. The final 22 miles of the river, downstream of Haverhill, Massachusetts, are tidally influenced (USACE 2003; NHDES 2019a).

The Merrimack River watershed has a total drainage area of approximately 5,010 square miles within the states of New Hampshire and Massachusetts, where about 3,800 square miles lie in New Hampshire and 1,200 square miles lie in Massachusetts (MEOEEA 2002). Lakes and ponds comprise 200 square miles, or four percent of the total area (Boott 1980). The Lowell Hydroelectric Project is located on the Merrimack River in Lowell, Massachusetts. The drainage area of the Lowell Project is approximately 3,979 square miles.

E.2.2 Tributary Rivers and Streams

The Merrimack River Basin (Basin) is the fourth largest river basin in New England (MEOEEA 2001). The Basin extends from the White Mountain region of northern New Hampshire to southeastern Massachusetts and spans the major cities of Laconia, Concord, Manchester, Nashua, in New Hampshire and Lowell, Lawrence, Haverhill, in Massachusetts. The Pemigewasset River flows for 64 miles, and the Winnipesaukee River stretches for ten miles. In addition to the Pemigewasset and Winnipesaukee River Basins, four principal tributaries contribute to the Merrimack River flow: the Contoocook, Piscataquog, Nashua, and Concord Rivers (USACE 2003; MEOEEA 2001). The Merrimack River Watershed and Major Subbasins are shown below in Figure E.2-1. The Lowell Project is located at RM 41 on the Merrimack River in the City of Lowell, Massachusetts. Several other smaller streams are contributory to the Merrimack or Concord Rivers within the City of Lowell and complete the major drainage pattern.

Figure E.2-1. Merrimack River Watershed and Major Subbasins



E.2.3 Topography

The Basin encompasses a variety of terrain as it ranges from steep, rugged conditions of the Northern New Hampshire White Mountain region to the estuarine coastal basin of northeastern Massachusetts (USACE 2003). The Basin is a part of the Eastern New England Upland physiographic unit containing three major sections -- the White Mountains, the New England Uplands, and the Seaboard Lowlands. The majority of the Basin is located in the New England Uplands, characterized by narrow floodplains and rolling hills ranging in elevation from below 1,000 feet to above 2,000 feet (USACE 2003). The Merrimack River itself drops 269 vertical feet over its long track to the Atlantic Ocean, with a more than 30-foot drop at the Project. The topography of the City of Lowell (13.4 square miles) is a combination of floodplain and, predominantly, gently undulating upland. The Merrimack corridor surface waters, in conjunction with the river's large watershed, form an extensive system of rivers, streams, lakes, ponds, wetlands and groundwater as well as densely forested lands consisting of evergreen or mixed evergreen-deciduous forests (NRPC 2008).

E.2.4 Dams and Diversion Structures within the Basin

There is a total of five[4] hydroelectric developments on the Merrimack River, comprising three separate Projects licensed by the Commission. Table E.2-1 presents information on the five FERC-regulated hydroelectric developments on the Merrimack River. All of the hydroelectric facilities on the Merrimack River operate in ROR mode.

In New Hampshire, there are four U.S. Army Corps of Engineers (USACE) flood storage dams within the Merrimack River basin. Boott and other licensees in the Merrimack River basin help to support the operational costs of these flood storage projects through Headwater Benefits payments assessed by FERC.

The USACE flood storage system in the Merrimack River basin consists of the following:

- Franklin Falls Dam is located in Franklin, New Hampshire, on the Pemigewasset River. The dam is three miles upstream of the confluence of the Pemigewasset and Winnipesaukee rivers where the Merrimack River originates. The dam is the key unit in the flood risk management for the Merrimack River basin. It provides flood protection for principal industrial and residential centers along the entire length of the Merrimack River. The construction of Franklin Falls Dam was completed in 1943, and it can store up to 50.2 billion gallons of water for flood control purposes (USACE 2016a).
- The Hopkinton-Everett Lakes Flood Risk Management Project consists of two dams, the dam at Hopkinton Lake, located on the Contoocook River in Hopkinton, New Hampshire, and the dam at Everett Lake, located on the Piscataquog River in Weare, New Hampshire. The two dams are connected by a two-mile-long canal and in moderate to severe flooding are operated as a single flood risk management

[4] The five hydroelectric developments on the Merrimack River do not include the four downtown mill power stations Boott is proposing to remove from the FERC license.

project. Construction of the project was completed in 1963. Together, the flood storage areas behind both dams can hold 52.6 billion gallons of water, which would cover approximately 8,000 acres (12.5 square miles). This is equivalent to 6.8 inches of water covering its drainage area of 446 square miles (USACE 2016b).

- The Blackwater Dam is located on the Blackwater River in Webster, New Hampshire. There is no lake at Blackwater Dam. The flood storage area of the project covers approximately 3,280 acres and extends upstream about seven miles through Salisbury, having a maximum width of one mile. Blackwater Dam can store up to 15 billion gallons of water for flood control purposes (USACE 2016c).

Table E.2-1. FERC-regulated Developments on the Merrimack River

Facility	FERC Project #	Licensee	River Mile	Generation Capacity (MW)
Garvins Falls (Merrimack River Project)	1893	CRP NH Amoskeag, LLC	87	12.3
Hooksett (Merrimack River Project)	1893	CRP NH Amoskeag, LLC	81	1.6
Amoskeag (Merrimack River Project)	1893	CRP NH Amoskeag, LLC	73	16
Lowell	2790	Boott Hydropower, LLC	40	20.2 (current) 15 (proposed)
Lawrence	2800	Essex Company, LLC	29	16.8

E.2.5 Wetland and Vegetative Cover

Wetlands and vegetative cover with the Project area appear to be consistent with these areas of New Hampshire and Massachusetts. Wetlands along the Merrimack River primarily consist of low-lying areas near and adjacent to the river, with other isolated wetlands farther away from the river proper. The wetlands directly surrounding the Lowell Project are largely considered riverine wetlands with an unconsolidated bottom. Riverine wetlands include all wetlands and deepwater habitats contained within a channel, with two exceptions: (1) wetlands dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and (2) habitats with water containing ocean-derived salts of 0.5 parts per thousand (or greater (Cowardin et al. 1979). The majority of the wetlands near or adjacent to the Project area are palustrine wetlands. Palustrine wetlands, often called fens, swamps, marshes, or bogs, are nontidal wetlands. These wetlands are dominated by trees, shrubs, and/or persistent plants/mosses. These wetlands may also be composed of shallow, open-water ponds (Cowardin et al. 1979). According to the USACE (2002), freshwater wetland habitats play an integral role in the ecology of the Merrimack River corridor. The combination of high nutrient levels and primary productivity found in these habitats is ideal for the development of organisms that form the base of the food web.

Natural forest cover encompasses 75 percent of the Basin and consists of a mix of deciduous and evergreen forest. Natural vegetation in the region consists of mesic to dry Appalachian oak-pine forests with various combinations of red oak (*Quercus rubra*), white oak (*Q. alba*), and black oaks (*Q. velutina*), some scarlet (*Q. coccinea*) or chestnut oaks (*Q. prinus*) to the south, white pine (*Pinus strobus*), sugar maple (*Acer saccharum*), red maple (*A. rubrum*), hickories (*Carya spp*.), and other central or northern hardwoods. Floodplain forests are typically dominated with silver maple (*A. saccharinum*), American elm (*Ulmus americana*), and green ash (*Fraxinus pennsylvanica*) (Griffith et al. 2009).

E.2.6 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. The climatic conditions of the Basin vary significantly from its headwaters in the White Mountains to its discharge along the Atlantic Ocean (USACE 2003). The Basin is located partially with the Northern and Coastal Climatic divisions, but the majority of the watershed falls within the Central Climatic division. The Central division is generally more moderate than the Northern section due to its lower elevation and latitude; this division experiences some climate modification due to maritime influences (USACE 2003; National Oceanic and Atmospheric Administration [NOAA] 2020a). Precipitation in the watershed is evenly distributed throughout the year and weather systems throughout the Basin operate primarily from prevailing westerly winds and the confluence of many continental weather patterns in North America. The Basin's climate is humid continental climate (Dfa/Dfb) according to the Köppen-Geiger climate classification.

NOAA data from 1897 to 2020 for the Boston, Massachusetts weather station indicates an average temperature of 52.1°F, with an average maximum temperature of 96°F and average minimum temperature of 2.0°F. The warmest temperatures occur in July and coolest temperatures occur in January. NOAA 1897 to 2020 data for Boston, Massachusetts shows an average annual precipitation of 41.45 inches with relatively even monthly averages. (NOAA 2020b).

Three predominant storm patterns occur in the Merrimack River Basin: continental, coastal, and local summer thunderstorms. Continental storms are associated with the usual easterly or northeasterly air flows that bring western or central storm disturbances to the Northeast. These continental storms are experienced in all months of the year. Coastal storms originate in the Gulf or southeast coastal states and bring moist, generally warmer air into the region (Boott 1980).

E.2.7 Major Land and Water Uses

E.2.7.1 Major Land Uses

Historically, the Merrimack River Basin played a large role in the development of the region's economy and land use patterns. The Industrial Revolution in the mid-1800s encouraged many families towards more promising work in urban settings. Many of the larger towns adjacent to the Merrimack River mainstem began as factory or mill towns due to the need for hydromechanical and later hydroelectric power to power the emerging industries. This economic shift from farming to urban settings resulted in the reclamation of previously predominantly agricultural lands by forest and woodland (USACE 2003; Boott 1980).

Although the Merrimack River watershed is heavily forested (75 percent of the land area is covered with forest), it also supports all or parts of approximately 200 communities with a total population of 2.6 million people (U.S Environmental Protection Agency [USEPA] 2020; USACE 2006). The population density in the Basin tends to increase from north to south as the lower region is characterized by five major urban cities along the Merrimack River: Manchester and Nashua in New Hampshire, and Lowell, Lawrence, and Haverhill in Massachusetts (USACE 2003). Basin population density ranges from fewer than 100 people per square mile in the northeastern and northwestern portions of New Hampshire, to greater than 800 people per square mile in Manchester and Nashua, New Hampshire, and northeastern Massachusetts. A majority (74 percent) of the Basin's urban area is residential while the remaining areas consist of commercial, transportation, industrial, and other urban use. In addition to the 75 percent forested land, the Basin generally consists of 13.3 percent urban land, four to five percent surface water, and 5.5 percent agriculture. Recreation and timber harvesting for lumber are the primary economic activities occurring in forested lands, while agricultural lands are dominated by hay and livestock farming (Flanagan 1999). Land use is discussed in further detail in Section E.7.6 of this application.

E.2.7.2 Major Water Uses

Consumptive users of the Merrimack River water are primarily municipal and industrial, with specific uses including domestic, thermoelectric, commercial, mining, livestock, and irrigation uses. Many of the municipalities bordering the Merrimack River, or within its watershed, use the river as a potable water source as well as a wastewater discharge point. The Merrimack River is the only major New England River used as a drinking water supply and is used as such by the communities of Lowell, Lawrence, Tewksbury, Methuen, and Andover in Massachusetts and Nashua, New Hampshire. Two more cities in New Hampshire, Manchester and Concord, plan to use the river for drinking water supply in the near future (MRWC 2018b).

E.2.8 Economic Activities

The Lowell Project is located in Middlesex County, Massachusetts and Hillsborough County, New Hampshire. According to the U.S. Census Bureau, the median household income from 2014-2018 (in 2018 dollars) is estimated to be $97,012 in Middlesex County, $78,655 in Hillsborough County, and $51,987 for the City of Lowell (U.S. Census Bureau undated). The main employment sectors in the region include professional, scientific, and tech services, educational services, healthcare and social assistance, manufacturing, and retail trade (Data USA undated).

E.3 Cumulative Effects (18 C.F.R. § 5.18(b)(2))

According to the Council on Environmental Quality's regulations for implementing NEPA (40 C.F.R. §1508.7), a cumulative effect is the impact on the environment which results from the incremental impact of a Proposed Action when added to other past, present, and reasonably foreseeable future actions, regardless of agency (federal or non-federal) or person undertaking such other actions. Cumulative effects can result from individually minor but collectively significant actions taking place over a period of time, including hydropower project operations and other land and water development activities.

E.3.1 Resources That Could Be Cumulatively Affected

Through scoping, agency consultation, review of the PAD, and Commission staff's preliminary analyses, the Commission noted in its Scoping Document 2 (SD2) that migratory fisheries in the Merrimack River have the potential to be cumulatively affected by the proposed continued operation and maintenance of the Project, in combination with other hydroelectric projects and other activities in the Merrimack River Basin.

E.3.2 Geographic Scope

The geographic scope of the cumulative effects analysis defines the physical limits or boundaries of the proposed action's effect on the resources. The geographic scope of analysis for cumulatively affected resources is defined by the physical limits or boundaries of: (1) the proposed action's effect on the resources, and (2) contributing effects from other dams within the Merrimack River Basin. In SD2, FERC identified the geographic scope for migratory fisheries to include Pemigewasset River from the Eastman Falls Dam and the Winnipesaukee River from the Lakeport Dam, to the confluence of the Winnipesaukee and Pemigewasset Rivers (which form the Merrimack River), and the Merrimack River downstream to the Atlantic Ocean. The Eastman Falls Dam (at river mile 1 of the Pemigewasset River) and the Lakeport Dam (at river mile 17 of the Winnipesaukee River and 4 miles downstream from the outlet of Lake Winnipesaukee) are migration barriers that represent the upstream limits to which river herring and American eel are managed within the river basin.

E.3.3 Temporal Scope

The temporal scope of the cumulative effect's analysis in this exhibit addresses past, present, and reasonably foreseeable future actions and their effects on each resource that may be cumulatively affected. Based on the potential terms of the new license, the Commission's SD2 defined the temporal scope of this analysis to address reasonably foreseeable actions 30-50 years into the future. Historical discussion would by necessity, be limited by the amount of available information for each resource. As noted in SD2, the quality and quantity of information are diminished as resources that are further away in time from the present are analyzed.

E.4 Compliance with Applicable Laws (18 C.F.R. § 5.18 (b)(3))

E.4.1 Section 401 of the Clean Water Act

Under Section 401 of the Clean Water Act (CWA), any federal license or permit to conduct any activity that may result in a discharge into navigable waters requires a certification from the state in which the discharge originates, that such discharge will comply with the applicable provisions of the CWA, unless such certification is waived. Therefore, a state Water Quality Certification (WQC) or waiver is a prerequisite for obtaining a license from FERC. The MADEP is the state agency designated to carry out the certification requirements as prescribed in Section 401 of the CWA for waters of the Commonwealth of Massachusetts. Pursuant to 18 C.F.R. § 5.23(b), Boott will file an application for a WQC with the MADEP within 60 days of FERC's Notice of Acceptance and Ready for Environmental Analysis. The MADEP must act on the request for a WQC within the one-year time frame allowed under the CWA.

E.4.2 Endangered Species Act

Section 7 of the Endangered Species Act (ESA) (19 U.S.C. § 1536(c)), as amended, requires federal agencies to ensure that their actions are not likely to jeopardize the continued existence of endangered or threatened species, or result in the destruction or adverse modification of the critical habitat of such species. Under the ESA, the United States Fish and Wildlife Service (USFWS) is responsible for freshwater and terrestrial species; and the National Marine Fisheries Service (NMFS; NOAA Fisheries) is responsible for marine and anadromous species.

In the Notice of the Licensee's Intent to File a License Application, Filing of the PAD, Commencement of the Pre-filing Process, and Scoping Document 1 issued on June 15, 2018, the Commission designated Boott as the Commission's non-federal representative for carrying out informal consultation, pursuant to section 7 of the ESA. Boott was granted designation as FERC's non-federal representative for Section 7 consultation on June 18, 2018. Information from the USFWS and the Massachusetts Division of Fisheries and Wildlife (MADFW) has been used by the Licensee to identify rare, threatened, and/or endangered (RTE) species in the Project area. A discussion of the RTE species relevant to this Project is contained in Section E.7.5 of this Exhibit.

E.4.3 Magnuson-Stevens Fishery Conservation Management Act

The 1996 amendments to the Magnuson-Stevens Act authorized the NMFS, in coordination with regional fisheries management councils, to delineate essential fish habitat (EFH) for the protection of habitat of marine, estuarine, and anadromous finfish, mollusks, and crustaceans. EFH includes "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity."

Based on a review of the NMFS online database, the Lowell Project reach of the Merrimack River is designated EFH under the Magnuson-Stevens Fishery Conservation and Management Act for Atlantic salmon (NOAA undated). This EFH was defined as "all waters currently or historically accessible to Atlantic salmon within the streams, rivers, lakes, ponds, wetlands, and other water bodies of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut" (New England Fishery Management Council [NEFMC] 1998).

E.4.4 Coastal Zone Management Act

Section 307(c)(3) of the Coastal Zone Management Act (CZMA) requires that activities conducted or supported by a federal agency that affect the coastal zone be consistent with the enforceable policies of the federally approved state coastal management plan to the maximum extent practicable. Section 307(c)(3) of the CZMA requires that all federally licensed activities that affect a state's coastal zone be consistent with the enforceable policies of the state's federally approved coastal management plan.

The Massachusetts Office of Coastal Zone Management (MOCZM) is the lead policy and planning agency on coastal and ocean issues within the Massachusetts Executive Office of Energy and Environmental Affairs (MEOEEA). In the preparation of the PAD, Boott initiated consultation with MOCZM, but has not received a response. By review of available coastal zone maps from the MOCZM, the activities associated with this project would fall outside the geographical boundaries of the Massachusetts Coastal Zone as delineated (MEOEEA 2014).

The New Hampshire Coastal Program (NHCP) is the lead policy and planning agency on coastal and ocean issues within the New Hampshire Department of Environmental Services (NHDES). In the preparation of the PAD, Boott initiated consultation with NHCP, but has not received a response. By review of available coastal zone maps from the NHDES, the activities associated with this project would fall outside the geographical boundaries of the Hew Hampshire Coastal Zone as delineated (NHDES undated).

As the Project is not subject to coastal zone management program review, no consistency certification is needed for FERC's relicensing of the Project.

E.4.5 National Historic Preservation Act

Section 106 of the National Historic Preservation Act (NHPA) (Section 106)8 requires federal agencies to take into account the effects of their undertakings on historic properties and to afford the Advisory Council on Historic Preservation (ACHP) a reasonable opportunity to comment on such actions. Historic properties include significant sites, buildings, structures, districts, and individual objects that are listed in, or eligible for listing in the NRHP. FERC's issuance of a new license for the Project is considered an undertaking subject to the regulations and requirements of Section 106 and its implementing regulations at 36 C.F.R. Part 800. In accordance with 36 C.F.R. §

800.14(b), FERC typically fulfills its responsibilities pursuant to Section 106 by entering into a Programmatic Agreement with the appropriate State and/or Tribal Historic Preservation Officer(s) (SHPO/THPO), and in some cases the ACHP.

FERC initiated consultation under Section 106 with federally recognized Indian tribes by letter dated April 26, 2017. By notice dated June 15, 2018, FERC designated Boott its nonfederal representative for purposes of conducting informal consultation pursuant to Section 106.

A discussion of historical properties within the Project's Area of Potential Effects (APE) and the consultation under Section 106 conducted to date for the relicensing of the Project is contained in E.7.8 of this Exhibit.

Early in the relicensing process, Boott contacted prospective stakeholders to determine their interest in this relicensing proceeding. As part of this outreach, Boott corresponded with representatives of the Massachusetts SHPO and federally recognized Indian tribes with a potential interest in the effects of this relicensing on historic properties. The Project does not occupy tribal reservation lands and the U.S. Bureau of Indian Affairs (BIA), via consultation, documented the following tribes as having historical interest in the Project area:

- Mashpee Wampanoag Tribe
- Wampanoag Tribe of Gay Head
- Penobscot Nation

By letter dated April 26, 2017, FERC invited the Mashpee Wampanoag Tribe, Narragansett Indian Tribe, Stockbridge Munsee Tribe of Mohican Indians, and Wampanoag Tribe of Gay Head (Aquinnah) to participate in the relicensing process for the Project. The Mashpee Wampanoag Tribe stated they do not have concerns with relicensing unless new construction is proposed that has the potential to disturb cultural resources.

E.4.6 Wild and Scenic Rivers and Wilderness Act

There are no rivers designated under the Wild and Scenic Rivers Act within or adjacent to the Project boundary; therefore, this act is not applicable to the relicensing of the Project. No Project facilities are located within any designated wilderness areas.

E.5 Project Facilities and Operation (18 C.F.R. § 5.18(b)(4))

E.5.1 Maps of Project Facilities within Project Boundaries (18 C.F.R. § 5.18(b)(4)(i))

The Lowell Hydroelectric Project boundary is shown in detail in Exhibit G of this license application. The physical composition, dimensions, and generation configuration of the facilities that comprise the Project are described in the following subsections.

E.5.2 Project Location and Facilities Overview (18 C.F.R. § 5.18(b)(4)(ii))

This section provides a summary of the existing facilities at the Project; additional, detailed descriptions of Project facilities are presented in Exhibit A of this license application.

The Project is located at the Pawtucket Dam on the Merrimack River in the City of Lowell in Middlesex County, Massachusetts. The Project is located approximately 11 miles upstream of the Lawrence Project (FERC No. 2800) and approximately 30 miles downstream of the Amoskeag Dam (a development of the Merrimack River Project, FERC No. 1893) in New Hampshire. The 116-mile-long Merrimack River begins at the confluence of the Winnipesaukee and Pemigewasset Rivers in Franklin, New Hampshire; flows southward into Massachusetts; and then travels northeast until it discharges into the Atlantic Ocean. The existing Project includes the 15.0 MW E.L. Field powerhouse constructed in 1985-1986 during Project redevelopment, and four smaller generating stations located within mill buildings along the downtown canal system. The current total installed capacity of the project is 20,164 kW. A Project location map is presented above as Figure E.1-1.

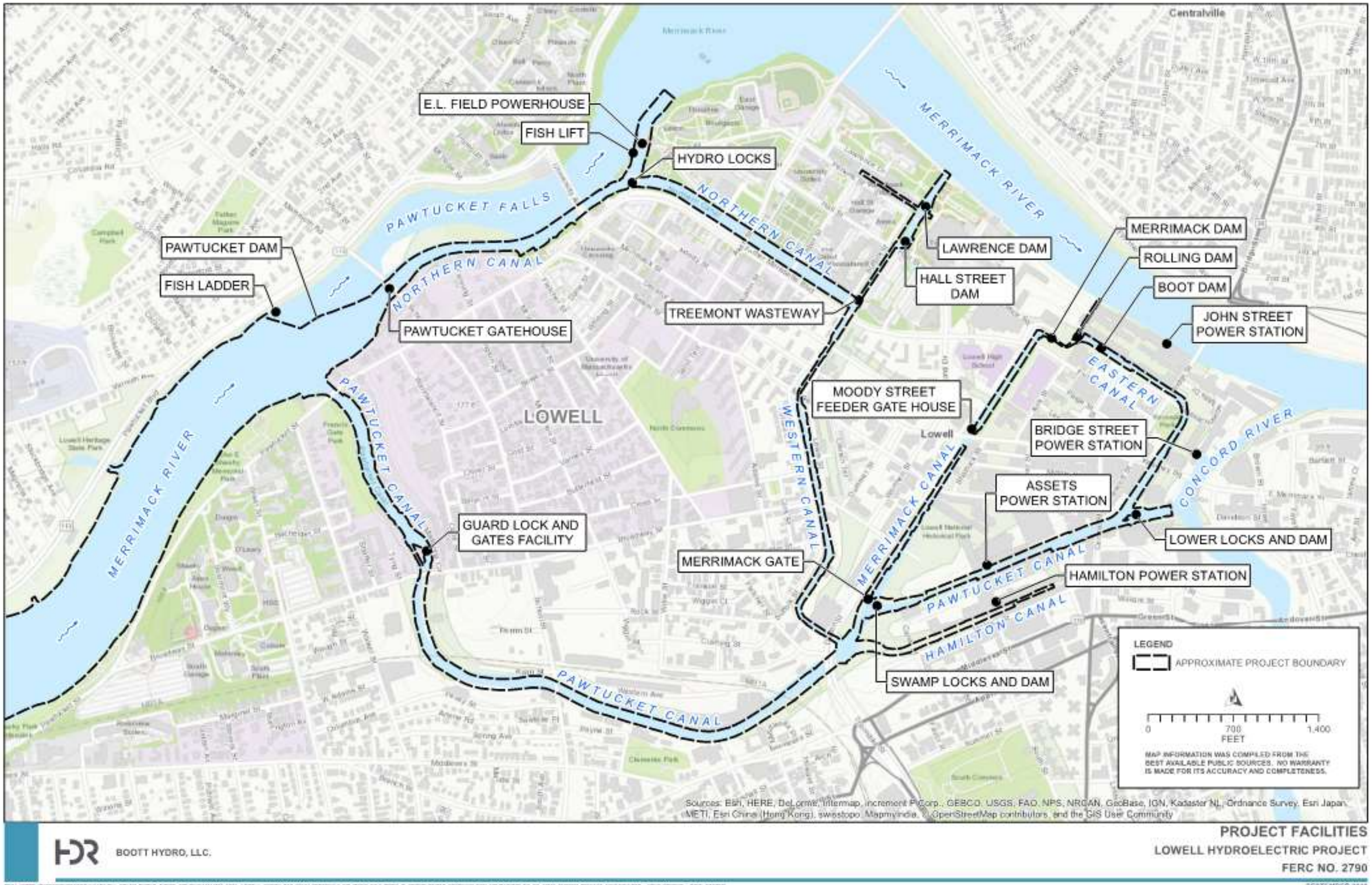
The E.L. Field powerhouse utilizes the existing Pawtucket Dam and the first 2,200 feet of the Northern Canal. The powerhouse is located close to the canal, downstream of the University Avenue Bridge (also called the Moody Street Bridge), with an intake structure drawing water from the canal. A 440-foot tailrace channel, surge gate and fish passage facilities comprise other major E.L. Field powerhouse features.

The current FERC license includes the Assets, Bridge Street, John Street, and Hamilton Power Stations which are housed within large nineteenth-century mill buildings sited along the 5.5-mile canal system (Figure E.5-1). Boott proposes to remove all four of these power stations from the new license. The current hydroelectric Project boundary includes only the turbines and associated equipment at these downtown mill sites. The Hamilton Power Station draws water from the Hamilton Canal and discharges into the Lower Pawtucket Canal. The Assets Power Station draws water through an intake structure at the Merrimack Canal and discharges into the Lower Pawtucket Canal. The Bridge Street Power Station (also known as “Section 8”) draws water from the Eastern

Canal and discharges into the Concord River. The John Street Power Station also draws water from the Eastern Canal and discharges into the Merrimack River.

As detailed in the Operations Analysis of the Lowell Canal Study (HDR 2021d), Boott notes that it is no longer economically feasible to operate these downtown power station units, and they have not been operated regularly in many years due to maintenance issues and other factors.

Figure E.5-1. Lowell Hydroelectric Project Canal System Map – Existing Facilities



E.5.3 Existing Structures Created Before Project Redevelopment

The site of the Lowell Project was historically used for hydromechanical and hydroelectric power for various mill operations. Much of the Project's current civil works were constructed during the 19th and early 20th centuries, and existed prior to Project licensing and redevelopment in the 1980's. These structures are described below.

E.5.3.1 The Pawtucket Dam

The Pawtucket Dam is of dressed masonry gravity construction with a length of 1,093 feet, a spillway crest length of 982.5 feet, a crest elevation of 87.2 feet NGVD 29, and an average height of 15 feet. Original drawings show the masonry was ashlar, laid dry with a mortared masonry upstream face at a 1:1 slope, a two-foot-thick capstone, and the bed course laid in mortar. It was built in two sections in 1847 and 1875, the latter being grouted during construction. The dam foundation rests on bedrock, except for a short section on hardpan. A fishway is located at the left dam abutment, and the Pawtucket Gatehouse to the Northern Canal is at the right abutment.

E.5.3.2 The Northern Canal

The Northern Canal is about 4,300 feet in length, with masonry or bedrock lining its complete length. The width of the Northern Canal varies along its length. At the head of the canal it is approximately 95 feet wide, at the location of the University Bridge overpass it is its most narrow at approximately 78 feet wide. About 2,200 feet downstream of the Pawtucket Gatehouse the canal widens to approximately 80 feet as it flows into the E.L. Field Powerhouse forebay. It then turns southeasterly at Pawtucket Street and Hydro Locks, widening to 105 feet between Pawtucket Street and the Tremont Gatehouse. In the new FERC license, Boott proposes to retain only the first ± 2,200-foot-long section of the Northern Canal extending from the Pawtucket Gatehouse to the E.L. Field forebay and Hydro Locks.

The Great River Wall is the left retaining wall of the Northern Canal. It runs from the Pawtucket Gatehouse to a natural rock outcrop upstream of the E.L. Field Powerhouse. The wall is a masonry structure that is 2,485 feet long and 32 feet in height. The first 1,000 feet combines masonry walls and an earth dike (with masonry core) as the river wall. The second length is a dressed masonry gravity structure to the site of the E.L. Field powerhouse. The crest of the Great River Wall is approximately 103.0 feet in elevation adjacent to the Pawtucket Gatehouse and varies in elevation along its length. The lowest point of the wall is approximately 93.3 feet at the University Bridge overpass. The width of the wall varies from 8 feet upstream at the Pawtucket Gatehouse to 10 feet at the downstream end. Boott proposes to retain the Great River Wall in the new FERC license.

E.5.3.3 Pawtucket Gatehouse

The Pawtucket Gatehouse (also known as the “Northern Canal Gatehouse”) is located at the southern abutment of the Pawtucket Dam and controls flow into the Northern Canal. It is principally constructed of dressed masonry with concrete over lintels and contains ten 8-foot-wide by 15-foot-high, motor-operated, timber sliding gates which feed the Northern Canal. Another small intake opening feeds an historic Francis-designed turbine, which formerly powered the gate mechanisms through a line shaft. The structure's water passages are nearly 80 feet in length. A small navigation lock is located on the located at the southerly end of the Pawtucket Gatehouse (Boott 2017). Boott proposes to retain the Pawtucket Gatehouse in the new FERC license.

E.5.3.4 The Pawtucket Canal

The Pawtucket Canal branches off the Merrimack River about 950 feet upstream of the Pawtucket Gatehouse and feeds water into the downtown canal system. From its starting point, the 9,000-foot canal curves south and then east to meet the Concord River near its junction with the Merrimack River. The width of the Pawtucket varies from 80 to 100 feet and the average depth is about 8 feet. The walls are of granite, ledge, or concrete. The canal beds are of ledge, concrete, or wood-planked virgin soil. Boott proposes to retain within the project boundary only the first approximately 1,600-foot-long section of the Pawtucket Canal, between the impoundment and the Guard Lock and Gates Facility.

E.5.3.5 Additional Canals

The Licensee’s existing four downtown power stations (Hamilton, Assets, Bridge Street, and John Street Power Stations) are fed by sections of the 5.5-mile canal system in Lowell. The principal canals in the system are the Pawtucket Canal and the Northern Canal, as described above. Smaller canals lead off these two major canals. The walls are of granite, ledge, or concrete. The canal beds are of ledge, concrete, or wood-planked virgin soil.

This Merrimack Canal branches off the Pawtucket Canal. In some areas the section is rectangular, but most of the Merrimack Canal has simply been gouged out of the native rock. The Merrimack Canal is 10 feet deep, 2,580 feet in length, and 40 to 50 feet wide. The Hamilton Canal begins at the Swamp Locks and is rectangular in section. The Hamilton Canal is 1,936 feet in length, 10 feet deep, 35 to 100 feet wide.

The Eastern Canal begins just above the Lower Locks of the Pawtucket Canal. The Eastern Canal runs for 2,037 feet and is rectangular in section. The Eastern Canal averages 8 feet in depth and 65 feet in width. The Western Canal was a two-level waterpower system, however the locks structures were removed and filled in 1840. The total length of the Western Canal is 4,964 feet. Its width varies from 35 to 55 feet, and its average depth is 9 feet.

As noted above, Boott proposes to remove all of these canals from the project boundary of the new FERC license, retaining only those portions of the Northern and Pawtucket Canal as described above. Boott will continue to manage the canal structures, water levels and flows using best practices and consistent with current agreements with the NPS and other stakeholders.

E.5.3.6 Miscellaneous Canal Structures

E.5.3.6.1 Guard Lock and Gates Facility

The Guard Lock and Gates facility consists of a five-bay gate house located on the Pawtucket Canal and a series of three gate structures located within a boat lock. The substructure of the gate house on the Pawtucket Canal is of dressed masonry, and the superstructure is of brick masonry and wood frame. Adjacent to this structure is a boat lock consisting of the upper locking gate, Great Guard Gate (or Francis Gate), and lower locking gate. The gates span the lock chamber which is 24 feet wide with masonry walls. The upper locking gate and Great Guard Gate are housed in frame buildings. Boott proposes to retain the Guard Lock and Gates facility within the new FERC license.

The Great Guard Gate is a large portcullis gate located within the lock chamber between the upstream and downstream lock gates. This 25' wide by 25' high wooden gate is designed to be lowered into the lock chamber during extreme flood conditions on the Merrimack River, to prevent flooding of downtown Lowell via the Pawtucket Canal. A wood frame structure, the Francis Gatehouse, houses the Great Gate. When needed, the Great Gate can be dropped under its own weight to the bottom of the lock chamber, thereby closing off any flow through the boat lock channel at the Guard Locks, preventing flooding in downtown Lowell via the Pawtucket Canal. The original Great Gate has been used only twice during its history, the year following its construction in 1852 and again in 1936.

Due to the historic nature, public safety concerns and questionable functionality of the historic Great Guard Gate, in 2005 Boott designed and implemented a replacement gate in consultation with the FERC and NPS. The replacement gate is a segmented structural steel stoplog gate and frame which is stored on-site. The steel stoplog gate was designed and implemented to functionally replace the historic Great Guard Gate, which remains in place within the Francis Gate House. The steel stoplog gate fits immediately upstream of the Francis Gate House within existing stoplog slots in the granite masonry. When required, installation of the steel stoplog gate can be accomplished within a few hours by a local crane operator. The Project's Emergency Action Plan (EAP) provides that the stoplogs should be installed when the water level at the Pawtucket Dam rises above 98.0 ft NGVD 29. To date, the steel stoplogs have been installed twice, during flooding events in May 2006 and April 2007.

E.5.3.6.2 Moody Street Feeder and Gate House

The Moody Street Feeder is a 1,400-foot-long underground conduit which allows flow to be passed from the Northern Canal to the Merrimack Canal. It terminates at the Moody Street Feeder Gate House which is located on the Merrimack Canal at the intersection of Dutton Street and Merrimack Street. Three 10-foot-wide gates allow closure of the three separate arched water passages. The gates are housed in a brick building measuring

62.5 feet long by 22.5 feet wide. Boott proposes to remove the Moody Street Feeder and Gate House from the new FERC license.

E.5.3.6.3 Lawrence Dam

The Lawrence Dam consists of a rock-filled timber-crib substructure with a three-tiered apron. The upper apron is of timbers overlaying rubble masonry. The second and third aprons consist of massive masonry. The superstructure is made of cast iron frames, fitted with wood bay boards. The structure is 100 feet long by 12 feet high and is located at the head of the Lawrence Wasteway, which leads to the Merrimack River. Boott proposes to remove the Lawrence Dam from the new FERC license.

E.5.3.6.4 Hall Street Dam

The Hall Street Dam consists of a rubble masonry structure with an upper protective timber deck and stepped massive ashlar masonry apron. The length of the structure is 115 feet with a maximum height of 15 feet. The dam is fitted with 1.5-foot flashboards. Boott proposes to remove the Hall Street Dam from the new FERC license.

E.5.3.6.5 Tremont Wasteway

The Tremont Wasteway is 30 feet wide by 600 feet long and is adjacent to Suffolk Street. The wasteway forms the water passageway between the Northern Canal and the Hall Street Dam. At the head of the wasteway is the Tremont Gate House. Two 9-foot-wide gates control the flow of water into the wasteway and are housed in a gate house building consisting of brick superstructure with masonry substructure. Boott proposes to remove the Tremont Wasteway from the new FERC license.

E.5.3.6.6 Lower Locks and Dam

The Lower Locks and Dam are on the Lower Pawtucket Canal and empty into the Concord River. The dam, with a maximum height of 12 feet, consists of a rubble masonry structure with a sloping timber apron. Energy dissipation is accomplished by large rubble masonry located downstream of the dam. The superstructure is constructed of cast iron frames, fitted with wood bay boards. A gated sluiceway is also provided. The lock structure contains two chambers 30.5 feet wide by 85 feet long. The width at the gate passageway is 12.5 feet. The lock walls are of hand laid masonry. Boott proposes to remove the Lower Locks and Dam from the new FERC license.

E.5.3.6.7 Swamp Locks and Dam

The Swamp Locks and Dam are at the head of the Lower Pawtucket Canal. The dam consists of a concrete apron overlaying a rubble masonry structure. The superstructure is made of cast iron frames, fitted with wood bay boards. The maximum height of the dam is 15 feet. A sluiceway, similar to the Lower Locks and Dam is also provided. A two-chamber lock, with narrowest width of 12.5 feet allows passage by the Swamp Locks and Dam. The lock is constructed of rubble masonry. Boott proposes to remove the Swamp Locks and Dam from the new FERC license.

E.5.3.6.8 Rolling Dam

The Rolling Dam consists of a masonry structure with curved apron protected by wood planks. The maximum height of the dam is 19 feet. The masonry construction is carried downstream of the dam to provide scour protection. The Rolling Dam is located downstream of the Merrimack Dam. Boott proposes to remove the Rolling Dam from the new FERC license.

E.5.3.6.9 Merrimack Dam, Merrimack Gate and Boott Dam

The Merrimack Dam consists of a sloping apron rubble masonry structure. The apron is protected with timber planks. The maximum height of the dam is 8 feet, and it acts as a submerged weir, no longer used to control water elevations.

The Merrimack Gate consists of a concrete dam structure with sloping upstream face and vertical downstream face. The center portion of the structure is fitted with a 10-foot-wide by 6-foot-high timber gate. The maximum height of the dam is 9 feet.

The Boott Dam is located 80 feet southeast of the Merrimack Wasteway adjacent to Boott Mills. It consists of a masonry structure 40 feet long with a maximum height of 7 feet and a gated sluiceway.

Boott proposes to remove the Merrimack Dam, the Merrimack Gate, and the Boott Dam from the new FERC license.

E.5.3.7 Mill Buildings

The Hamilton, Assets, Bridge Street, and John Street power stations and turbines are housed in large old mill buildings. The buildings, not included in the Project, are exceptionally sturdy structures used principally as space for small industrial manufacturers, storage space or apartment/condominium units. The existing hydroelectric Project boundary includes only the turbines and associated equipment at these downtown mill sites. Boott proposes to remove these turbines and associated water passages from the new FERC license.

E.5.4 Structures Constructed During Project Redevelopment

The principal civil works constructed during project redevelopment in 1985-1986 include the E.L. Field powerhouse, associated intake and tailrace channels, a canal control structure with navigation lock, fish passage facilities and a substation. Boott proposes to retain all of these structures within the new FERC license.

E.5.4.1 Eldred L. Field Powerhouse

The E.L. Field powerhouse is a reinforced concrete structure. The powerhouse is approximately 109 feet long by 96 feet wide and houses two generating units with a total authorized generation of 15.0 MW. The powerhouse incorporates a separate conventional intake structure for each of the station's two identical units. Each intake is equipped with trashracks; intake and draft tube gate slots with permanent or bulkhead style gates for emergency shutdown and dewatering purposes are also provided. The powerhouse is equipped with a traversing trash rake to remove debris at the intake. Both mobile and on-site cranes are used for heavy equipment movement at the facility.

E.5.4.2 Tailrace Channel

A 440-foot-long tailrace channel was excavated out of bedrock in the river. The channel excavation is approximately 60 feet wide by an average of 20 feet deep. The tailrace is protected from high river flows by a 10 to 16 -foot-high concrete training wall, which directs bypassed river flows away from the tailrace.

E.5.4.3 Crest Gate System

A pneumatically operated crest gate system is mounted on the spillway crest to maintain the headpond at its normal maximum water surface elevation of 92.2 feet NGVD 29. The pneumatic crest gate system consists of five-foot-high, 20-foot-long hinged steel panels supported on their downstream side by tubular rubber air bladders. The crest gate system is installed in five independently controllable zones. Air compressors, which supply system inflation and deflation pressure, and the crest gate control system are housed in a building located near the fish ladder and the left (northerly) abutment of the dam.

E.5.4.4 Control Structures

During the construction of the E.L. Field powerhouse in the 1980's a concrete control structure known as "Hydro Locks" was constructed at the bend in the Northern Canal upstream of the E.L. Field intake and underneath the Pawtucket Street Bridge. The control structure was constructed to maintain effective net head at the E.L. Field Powerhouse by isolating the powerhouse forebay from the remainder of the Lowell canal system. It includes a navigation lock at its western end to allow passage of NPS tour boats.

Located along the Great River Wall is the canal surge gate, located just upstream of the E.L. Field Powerhouse. The steel gate is pneumatically operated and is 15-feet-high by 78 feet wide set on a masonry weir with a crest elevation of 77.0 feet. This system is designed to attenuate the surge wave in the canal that occurs when there is a sudden plant shutdown. When flow is less than 3,500 cubic feet per second (cfs), the surge suppressor gate is manually disabled. Should the flow increase to over 3,500 cfs, the gate is returned to the automatic operating condition. A safety boom has been installed in the canal above the gate.

E.5.4.5 Fish Passage Facilities

Upstream and downstream fish passage facilities at the Project include a fish elevator[5] and downstream fish bypass at the E.L. Field powerhouse, and a vertical-slot fish ladder at the Pawtucket Dam. All fish passage facilities were designed in consultation with the U.S. Fish and Wildlife Service. Passage operations are supervised by the state and federal fishery agencies.

The reinforced concrete fish ladder at the Pawtucket Dam is designed to allow for controlled fish passage at river flows up to 25,000 cfs The fishway operates at 200 cfs, including attraction flow, with an additional 300 cfs of supplemental attraction flow released from a slide gate adjacent to the passage facility. The fish ladder is a vertical slot design with 13-foot-wide by 10-foot-long pools. A counting station and fish trap area is provided. The Pawtucket Dam has been modified by removing ashlar masonry to allow the exit channel to penetrate the dam.

The upstream fishway at the powerhouse is a fish elevator. The design discharge capacity is 200 cfs. A fish collection gallery with two openings spans the downstream wall of the powerhouse to collect fish migrating through the tailrace channel, however only the westerly "river side" entrance has been used since the 1990's, by agreement with the fishery agencies. The fish are attracted into the 30-foot crowding pool, trapped, and crowded. From the crowding pool, they enter the elevator and are lifted in a hopper to the exit channel. From the elevator area, the fish enter a holding pool 10 feet wide by 50 feet long. Fish next enter the fish trap area where they can be counted. A 10-foot by 12-foot fish counting station is provided. Passage of fish through the trap area allows fish to enter the exit channel, passing into the Northern Canal and then upriver.

The downstream fishway at the powerhouse consists of an adjustable-flow sluiceway and bypass adjacent to the intake headwall. Downstream migrants entering the bypass are quickly sluiced into an enlarged and deepened plunge pool located in the bypassed river reach next to the powerhouse. Natural channel braids in the riverbed allow emigrants to move downstream to the mainstem river, at the confluence of the river reach and tailrace.

E.5.4.6 Impoundment Characteristics (18 C.F.R. §5.18 (b)(4)(iii)

The Project operates in a ROR mode and has no usable storage capacity. The existing Project boundary extends approximately 23 miles upstream to Moore's Falls in Litchfield and Merrimack, New Hampshire.

Boott is proposing to remove 7.4 miles from the upstream extent of the current Project boundary, as shown in Exhibit G. At the normal pool elevation of 92.2 ft NGVD 29, the surface area of the proposed impoundment is reported to encompass an area of about 1,236 acres. The gross storage capacity between the normal surface elevation of 92.2

[5] The terms "fish elevator" and "fish lift" are used interchangeably in this document to describe the existing upstream fish passage facility at the E.L. field Powerhouse.

feet NGVD 29 and the minimum pond level of 87.2 feet NGVD 29 is approximately 6,180 acre-feet.

E.5.4.7 Generating Equipment (18 C.F.R. §5.18(b)(4)(iv)

Turbine and generator data for each of the five existing power stations (including the E.L. Powerhouse) are provided below in Table E.5-1. Boott proposes to remove all of the mill powerhouse units from the new FERC license, leaving only the two units at the E.L. Field Powerhouse. The proposed project capacity is 15,012 kW.

Table E.5-1. Lowell Hydroelectric Existing Project Turbine, Generator, and Unit Capacity Data

		TURBINES							GENERATORS							
			Size	Speed	Head	Flow	Power	Power			Power	Power	Voltage	Speed		Unit
Powerhouse	Unit #	Type	Inches	RPM	Feet	cfs	HP	kW	Type	kVA	Factor	kW	Volts	RPM		Capacity
E. L. Field	1	Fuji Horizontal Full Kaplan	152.4	120	39	3,300	11,540	8,655	Fuji Electric	8,340	0.9	7,506	4,160	120		7,506
E. L. Field	2	Fuji Horizontal Full Kaplan	152.4	120	39	3,300	11,540	8,655	Fuji Electric	8,340	0.9	7,506	4,160	120		7,506
Assets	1	Hercules Double Runner Styles C & D	33 / 31	150	13	376	444	333	General Electric Type ATB 48-332-150	330	0.8	264	600	150		264
Assets	2	Hercules Double Runner Styles C & D	33 / 31	150	13	376	444	333	General Electric Type ATB 48-332-150	330	0.8	264	600	150		264
Assets	3	Hercules Double Runner Styles C & D	33 / 31	150	13	376	444	333	General Electric Type ATB 48-332-150	330	0.8	264	600	150		264
Bridge Street	4	Hercules Type D Single Runner	42	138.5	22	333	655	491	General Electric Co. Type ATB	450	0.8	360	600	138.5		360
Bridge Street	5	Hercules Type D Single Runner	42	138.5	22	333	655	491	General Electric Co. Type ATB	450	0.8	360	600	138.5		360
Bridge Street	6	Hercules Type D Single Runner	42	138.5	22	333	655	491	General Electric Co. Type ATB	450	0.8	360	600	138.5		360
Hamilton	1	Leffel Type Z Single Runner	45	120	13	374	459	344	Westinghouse Electric Co.	350	0.8	280	600	120		280
Hamilton	2	Leffel Type Z Single Runner	39	133	13	279	341	256	Electric Machinery Co.	225	0.8	180	600	133		180
Hamilton	3	Leffel Type Z Single Runner	36	150	13	237	287	215	Electric Machinery Co.	200	0.8	160	600	150		160
Hamilton	4	Leffel Type Z Single Runner	45	120	13	374	459	344	Electric Machinery Co.	350	0.8	280	600	120		280
Hamilton	5	Leffel Type Z Single Runner	45	120	13	374	459	344	Electric Machinery Co.	350	0.8	280	600	120		280
John Street	3	Leffel Single Runner	33	200	21	250	482	362	General Electric Co. Type ATI	375	0.8	300	600	200		300
John Street	4	Leffel Single Runner	33	200	21	250	482	362	General Electric Co. Type ATI	375	0.8	300	600	200		300
John Street	5	Leffel Single Runner	33	200	21	250	482	362	General Electric Co. Type ATI	375	0.8	300	600	200		300
John Street	6	Allis Chalmers Single Runner	72	100	21	1,000	1,925	1,444	Allis-Chalmers Type AV	1,500	0.8	1,200	600	100		1,200
											TOTAL PROJECT CAPACITY:					20,164

E.5.5 Estimated Average Annual Energy Production (18 C.F.R. §5.18(b)(4)(v)

The average annual energy generation of the Lowell Hydroelectric Project for the period of 2008 through 2017 was 84,501 megawatt-hours (MWh). The Project operates in a ROR mode and, therefore, experiences seasonal and annual variations in generation based on natural hydrologic conditions in the Merrimack River Watershed. Table E.5-2 provides a summary of monthly Project generation for a 10-year period from 2008 through 2017 in MWh.

Table E.5-2. Lowell Hydroelectric Project Monthly and Annual Generation (MWh)

Month	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
January	10,610	2,574	6,403	7,163	10,272	8,064	10,422	6,624	9,258	9,325
February	10,955	3,851	6,672	5,228	8,928	8,304	5,232	3,216	9,312	6,335
March	11,727	5,088	8,555	10,176	12,432	12,784	10,536	5,820	10,042	9,395
April	10,876	7,341	8,061	11,088	7,872	13,392	10,959	10,128	8,427	8,387
May	7,690	10,147	8,094	11,472	11,712	9,600	9,264	5,219	7,244	8,181
June	4,512	10,464	4,752	8,304	9,792	11,551	3,075	6,563	2,577	9,716
July	5,615	11,252	2,963	3,552	3,216	11,520	4,608	6,432	1,010	6,635
August	4,810	8,026	2,072	4,416	4,560	6,144	5,472	2,412	1,044	2,959
September	4,962	4,012	1,677	10,128	3,696	6,214	4,428	1,898	498	3,462
October	5,287	5,703	8,457	11,136	7,344	3,894	4,314	5,297	1,059	3,332
November	4,726	4,404	10,216	10,272	6,384	5,376	6,880	6,367	3,649	7,380
December	4,656	4,747	9,687	10,272	8,880	7,772	10,700	8,395	9,025	7,946
Annual	86,425	77,609	77,608	103,207	95,088	104,614	85,890	68,371	63,146	83,053

E.5.6 Estimated Dependable Capacity (18 C.F.R. §5.18(b)(4)(v)

Dependable capacity is generally defined as the amount of load a hydroelectric plant can carry under adverse hydrologic conditions during a period of peak demand, for example, during the hot, dry conditions typical of August in the Project area. The estimated dependable capacity is also determined by the minimum flow requirements included in the existing license. Under the current license, the Project's estimated dependable capacity is approximately 4.9 MW, based on the August median flow of 1,940 cfs at the Project site. The estimated dependable capacity is not expected to change with removal of the four power stations along the downtown canal system given they were only operated during flow conditions over 6,600 cfs.

E.5.7 Current and Proposed Project Operations (18 C.F.R. §5.18(b)(4)(vi)

The Project is operated using the automatic pond level control capability of the E.L. Field Powerhouse. Boott is proposing to continue to operate the Project in the same manner as it is currently operated (automatic).

E.5.7.1 General Operations

The Project is operated in a ROR mode. Under the current project configuration, Boott normally operates the Project to maximize flow through the available units at the E.L. Field Powerhouse, then routes any additional flows through the Pawtucket Canal system. The E.L. Field turbine-generator units are more efficient and operate at a higher head than the older canal units, and are, therefore, the priority first-on, last-off units in the Project operations scheme. When river flows exceed the hydraulic capacity of the E.L. Field units (nameplate hydraulic capacity = 3,300 cfs per unit or 6,600 cfs for both units), excess flows up to approximately 2,000 cfs may be routed through the downtown canal system and to the canal units. Any flows in excess of approximately 8,600 cfs (6,600 cfs at E.L. Field plus 2,000 cfs via canals) are passed over the Pawtucket Dam spillway. Pursuant to Article 37, the Project maintains a minimum flow of 1,990 cfs or inflow, whichever is less, as measured immediately downstream from the Project, which is met or exceeded by operating the project in ROR mode (Boott 2017).

Project operations will not change significantly with the proposed removal of the 15 mill units and associated canal infrastructure from the new license. The Project will continue to operate in ROR mode using automatic pond level control of the E.L. Field powerhouse units, passing all excess flow over the spillway of the Pawtucket Dam. Boott will continue to manage flow passed through the Guard Locks on an as-needed basis for water level and flow management purposes within the downtown canal system.

E.5.8 Pneumatic Crest Gate Operations

On April 18, 2013, FERC authorized Boott to replace the existing wooden flashboard system on the Project's Pawtucket Dam with a pneumatic crest gate system. FERC approved the amended crest gate system operation plan on March 30, 2015. The plan describes the operation of the pneumatic crest gate system under normal and high-water operations.

The pneumatic crest gate system works in conjunction with the automatic pond level control system at the E.L. Field Powerhouse to maintain consistent headpond level conditions.

Below (Table E.5-3) is a tabular description of the operating curve currently used for operations.

Table E.5-3.Pneumatic Crest Gate System Current Operational Scheme

Approximate Spillway Flow (cfs) †	Crest Gate Status	Target Pond Level (ft NGVD 1929)	Unit Operation
0	Full elevation	92.2 ft (Normal pond)	Pond level control maintained at E.L. Field Powerhouse; additional flow passed through downtown canal system as necessary.
0 – 3,250	Full elevation	Rising to ± 93.2 ft	Full available output
3,250 - ± 23,000 (est.)	Automatic pond level control	± 93.2 ft	Full available output
± 23,000 (est.) – 35,000††	Automatic pond level control if High Water Operations Protocol is not triggered.	± 93.2 ft	Full available output
	Fully lowered if High Water Operations Protocol is triggered	Pond level follows spillway rating curve based on spillway flow.	Full available output
>35,000	Fully lowered	Rises above 93.2 ft as spillway discharge increases.	Fully available output

Source: FERC 2015.
† Flow over the spillway is the inflow to the headpond minus any flow through the turbines at the E.L. Field Powerhouse, through the downtown canal system or through the fish ladder. The maximum combined hydraulic capacity of E.L. Field Powerhouse and the canal system is approximately 9,000 cfs, but may be restricted by unit availability, debris accumulation at the Northern Canal Gatehouse, high tailwater conditions, and other factors.
†† The potential range of spillway flows over which the crest gate may be fully lowered per the High-Water Operations Protocol. The estimated flow over the spillway is the flow at the Merrimack River (U.S. Geological Survey [USGS] gage No. 01100000) minus the flow at the Concord River (USGS gage No. 01099500) and minus any flow released through Boott's turbines and the downtown canal system.

E.5.8.1.1 Normal Operation

Under normal operations, the crest gate will be maintained at full elevation, and the E.L. Field Powerhouse control system will adjust the main units' output to match inflow and maintain the impoundment water level at the normal, authorized pond elevation.

E.5.8.2 Operations During Low Water and Adverse Conditions

During low inflow conditions, Boott operates the Project to maintain the impoundment level of 92.2 feet NGVD 29 and provides the required minimum downstream releases and flows necessary for operation of the fish passage structures in accordance with Articles 36 and 37 of the Project's license.

Boott also proposes to release a minimum flow of 100 cfs or inflow, whichever is less, to the bypass reach downstream of the Pawtucket Dam during the period outside of the fish passage season. The minimum flow would be provided as spillage over one or more of the crest gate zones.

E.5.8.3 Operations During High Water and Adverse Conditions

Under past and current operations, when river flows exceed the hydraulic capacity of the E.L. Field Powerhouse units (approximately 3,300 cfs per unit or 6,600 cfs for both units), excess flows up to approximately 2,000 cfs can be routed through the downtown canal system and to the canal units (as described below). Any flows in excess of these flows are passed over the Pawtucket Dam spillway.

During these high-water conditions, the crest gate control system will automatically adjust the gates to maintain the impoundment elevation no higher than 93.2 feet NGVD 29, or one foot above the normal pond elevation. When under automatic control, the crest gates would all be fully lowered at spillway flows of approximately 35,000 cfs. In addition, the approved crest gate operations plan requires Boott to fully lower the crest gate panels in anticipation of potential flood events. This minimizes the upstream backwater effect of the Pawtucket Dam to the extent possible. (FERC 2015).

Under very high flow conditions when the water level at the Pawtucket Dam reaches 98.0 feet NDVD 29, Boott initiates the installation of the steel stoplogs upstream of the Great Guard Gate, per the provisions of the EAP, as discussed in detail under Section E.5.6.3.1. These stoplogs are designed to functionally replace the historic Great Guard Gate, to prevent the potentially flooding of downtown Lowell via the Pawtucket Canal.

E.5.8.4 Canal System Operations

The existing Lowell Hydroelectric Project includes a two-tiered network of man-made canals, totaling 5.5 miles in length. Flow enters the canal system upstream of the Pawtucket Dam via the Pawtucket Canal and is controlled by the Guard Lock and Gates Facility.

The Lowell Hydroelectric Project presently includes four power stations located within mill buildings along the downtown canal system. The Hamilton Power Station contains five units and draws water from the Hamilton Canal in the upper canal system and discharges into the Lower Pawtucket Canal in the lower canal system at a head of approximately 13 feet. The Assets Power Station contains three units and draws water from the Merrimack Canal in the upper canal system and discharges into the Lower Pawtucket Canal in the lower canal system at a head of approximately 13 feet. In the lower canal system, the Bridge Street and John Street Power Stations each draw from the Eastern Canal and discharge to the Merrimack River or the Concord River, at a head of approximately 21 feet. The John Street Power Station contains four units and discharges into the Merrimack River. The Bridge Street Power Station has three units known as "Section 8" discharging into the Concord River.

As stated elsewhere in this application for license, Boott proposes to remove the four mill power stations and associated canal infrastructure from the new FERC license. Boott will continue to manage the canal structures, water levels and flows in line with current agreements with the NPS and other stakeholders.

E.5.8.4.1 Minimum Flow Management

Although there is no formal flow requirement for the canal system, Boott maintains an operating agreement with the NPS to allow tour boat operations to navigate the canal system. Boott maintains canal water levels within appropriate limits during the May 15 to October 15 tour boat operating season. Operations are maintained through a series of locks and gatehouses along the canal system (Cleantech Analytics 2017).

E.5.8.4.2 Normal Operation

The nominal flow capacity of the downtown canal system via the Pawtucket Canal and the Guard Lock and Gates Facility is approximately 2,000 cfs. Future normal operations will consist of providing sufficient flow through the Guard Gates structure necessary to maintain and manage water levels in the downtown canal system, consistent with current practices and agreements.

E.5.8.4.3 Operation During High Water

As discussed in Section E.5.7.1, when river flows exceed the hydraulic capacity of the E.L. Field Powerhouse units (6,600 cfs for both units), excess flows up to approximately 2,000 cfs can be routed through the downtown canal system and to the canal units. Any flows in excess of these capacities are passed over the Pawtucket Dam spillway. Under proposed future operations Boott does not anticipate any need to pass excess flow through the canal system, since the Pawtucket Dam spillway has ample capacity and the crest gates would be fully lowered during high flow events.

The Guard Lock and Gates facility includes the Great Guard Gate, a large portcullis gate constructed in 1851 to prevent flooding in downtown Lowell via the Pawtucket Canal. In 2005 Boott designed and implemented a replacement for the historic Great Guard Gate. The replacement gate is a segmented structural steel stoplog gate and frame which is stored on-site and was designed and implemented in consultation with the FERC and NPS. When required, installation of the steel stoplog gate can be accomplished within a few hours by a local crane operator. The Project's Emergency Action Plan (EAP) provides that the stoplogs should be installed when the water level at the Pawtucket Dam rises above 98.0 ft NGVD 29. Boott proposes to retain the Great Guard Lock and Gates facility in the Project license, and to continue implementation of the existing EAP associated with the facility.

E.5.8.5 Fish Passage Operations

The Comprehensive Fish Passage Plan (CFPP), approved by FERC on November 28, 2000, required operation of a fish ladder at the Pawtucket Dam. The fish ladder has a total operating flow of 500 cfs including attraction flow. The 500 cfs is the primary source of flow in the bypass reach, other than spillage over the Pawtucket Dam spillway. The fish lift system at E.L Field Powerhouse has a total flow capacity of 180 cfs; however, it presently operates at 100-120 cfs. Boott is required to operate both the fish ladder and the fish lift daily during spring of each year when a cumulative total of 50 American shad (*Alosa sapidissima*) or 200 River herring (*A. pseudoharengus*) are passed at the downstream Lawrence Hydroelectric Project. Additionally, Boott is required to operate the downstream bypass facility from April 1 through July 15 and from September 1 through November 15 (Cleantech Analytics 2017). All fish passage facilities were designed in consultation with the USFWS. Since 2013, Boott has worked cooperatively with the USFWS and other fishery agencies as part of the Merrimack River Technical Committee (MRTC) to assess and provide passage for eels moving upstream in the mainstem Merrimack. The efforts have occurred primarily at the fish ladder at the Pawtucket Dam, from mid-July through September, annually. Fish passage operations are coordinated with the MRTC.

Under the new Project license, Boott proposes to replace the existing fish lift with a short fish ladder to pass migratory fish from the tailrace to the bypass reach, such that all fish would be passed upstream of the Project via the existing fish ladder at the Pawtucket Dam. The Licensee will work with the MRTC member agencies to determine the design and installation schedule for the proposed ladder.

E.5.9 Proposed Project Operations (18 C.F.R. §5.18(b)(4)(vi))

The Project is operated in a ROR mode with no useable storage capacity, and a minimum flow of 1,990 cfs (or inflow, whichever is less) is provided immediately downstream from the Project for the purpose of protection of fish and wildlife resources. Boott also adheres to the CFPP (approved by FERC on November 28, 2000) and the Crest Gate Operation Plan (approved March 30, 2015).

Boott also proposes to release a minimum flow of 100 cfs or inflow, whichever is less, to the bypass reach downstream of the Pawtucket Dam during the period outside of the fish passage season. The minimum flow would be provided as spillage over one or more of the crest gate zones. During the fish passage season, which generally runs from late April through mid-July, the Licensee proposes to release a minimum flow of 500 cfs into the bypass reach via the existing fish ladder at the Pawtucket Dam. The operating period for the fish ladder will continue to be determined annually through consultation with the fishery agencies, consistent with current practice.

E.6 Proposed Action and Action Alternatives

E.6.1 Summary of Existing Measures

Boott currently implements the following PM&E measures for the protection of aquatic, water quality, geologic/soil, recreation, and cultural resources pursuant to the existing license for the Project.

Article 33 (amended April 18, 2013 and approved May 18, 2016): Requires the Licensee, prior to the commencement of any construction activities, to cooperate with the Massachusetts State Historic Preservation Officer (SHPO) and the NPS to carry out a mitigation program for avoiding or minimizing adverse effects on the Locks and Canals Historic District and the Lowell National Historical Park (The license was amended to replace wooden flashboards on Pawtucket Dam with pneumatic crest gate system and mitigation measures were required).

Article 34 (approved September 24, 1984): Requires the Licensee to design and construct upstream and downstream fish passage facilities at the Project, in consultation with the fishery agencies. Accordingly, in the late 1980s the Licensee constructed a fish lift and downstream fish passage facility at the E.L. Field powerhouse and a fish ladder at the Pawtucket Dam. These facilities are operated and managed under the CFPP, as discussed below.

Article 35 (approved November 28, 2000): Requires the Licensee to conduct an operational study to determine the effectiveness of the fish passage facilities required under Article 34, in consultation with the fishery agencies. During the term of the license The Licensee has conducted numerous fish passage studies and has implemented operational and facility improvements based on the results of those studies. These studies and improvements have been carried out pursuant to the CFPP, as discussed below.

Article 36 (approved November 27, 1984; November 28, 2000; July 11, 2001): Required the Licensee develop (1) an instream flow study plan to determine the relationship between Project discharges and downstream aquatic habitat, and (2) a fishery study plan to determine Project discharges necessary to provide for the migration of anadromous fish.

Pursuant to Article 35 and 36, Boott adheres to the Comprehensive Fish Passage Plan, approved by FERC on November 28, 2000.The CFPP requires operations of a fish ladder at the Pawtucket Dam. The fish ladder has a total operating flow of 500 cfs including attraction flow. The 500 cfs is the primary source of flow in the bypass reach, other than spillage over the Pawtucket Dam spillway. The fish lift system at E.L Field Powerhouse has a total flow capacity of 180 cfs; however, it presently operates at 100-120 cfs. Boott is required to operate both the fish ladder and the fish lift daily during spring of each year when a cumulative total of 50 American Shad or 200 River Herring are passed at the downstream Lawrence Hydroelectric Project. Additionally, Boott is required to operate the downstream bypass facility from April 1 through July 15 and from September 1 through November 15 (Cleantech Analytics 2017).

Since 2013, Boott has worked cooperatively with USFWS and other fishery agencies to assess and provide passage for eels moving upstream in the mainstem Merrimack. The efforts have occurred primarily at the fish ladder at the Pawtucket Dam, from mid-July through September, annually.

Article 37 (ordered November 27, 1984): Requires the Licensee to discharge an interim continuous minimum flow of 1,990 cfs or inflow, whichever is less, for the purpose of protection of fish and wildlife resources, as measured immediately downstream from the Project.

Article 38 (ordered September 12, 1984): Requires the Licensee to file a revised Report on Recreational Resources to include: (1) functional plans for certain repairs and improvements to the Northern Canal and a visitor facility at the E.L. Field Powerhouse; (2) a canal system water level agreement with the NPS.

Boott is also required to adhere to the following operations-related plan:

Crest Gate Operation Plan (approved March 30, 2015): Requires the Licensee to adhere to the detailed plan for operation of the pneumatic crest gate system filed on July 16, 2013 and revised on July 30, 2014. The plan describes the operation of the pneumatic crest gate system under normal and high-water operations. Table E.5-3 above provides a tabular description of the operating curve used for operations.

The pneumatic crest gate system works in conjunction with the automatic pond level control system at the E.L. Field Powerhouse to maintain consistent headpond level conditions. Under normal operations, the crest gate will be maintained at full elevation, and the E.L. Field control system will adjust the main units' output to match inflow and maintain the impoundment water level at the normal, authorized pond elevation (92.2 feet). When inflows begin to exceed the capacity of the available units, the crest gate control system will automatically adjust the gates to maintain the impoundment elevation no higher than 93.2 feet, or one foot above the normal pond elevation. When under automatic control, the crest gates would all be fully lowered at spillway flows of approximately 35,000 cfs and above (FERC 2015a). Under high-water operations, Boott will fully lower the crest gate system in anticipation of potential flood events in order to minimize the upstream backwater effect of the Pawtucket Dam to the extent possible.

E.6.2 Summary of Proposed Measures

Based on the studies conducted in support of this relicensing and consultation with stakeholders to date, Boott proposes the following measures to be included in the new Project license:

<u>Project Facilities and Operations</u>

- Boott proposes to operate the Project in a ROR mode using automatic pond level control of the E.L. Field powerhouse units, to protect fish and wildlife resources downstream from the Project. ROR operation may be temporarily modified for short periods to allow flow management for other project and non-project needs, e.g., downtown canal water level management, raising the crest gates following a high-water event, or for recreational purposes.

- During the upstream fish passage season, which generally runs from late April through mid-July, Boott proposes to release a minimum flow of 500 cfs into the bypass reach via the existing fish ladder at the Pawtucket Dam. The operating period for the fish ladder will continue to be determined annually through consultation with the Merrimack River Technical Committee,[6] consistent with current practice. At all other times, Boott proposes to release a minimum flow of 100 cfs or inflow, whichever is less, to the bypass reach downstream of the Pawtucket Dam, for the protection of aquatic habitat within the bypass reach.
- Boott proposes continued adherence to the requirements of the Project's existing Crest Gate Operation Plan (approved by FERC on March 30, 2015).
- Boott proposes to remove the four mill power stations and associated canal infrastructure from the new FERC license. Boott will continue to manage its canal structures and facilities, water levels and flows through the downtown canal system in line with the current agreements with NPS and other stakeholders.
- Boott understands that removal of the fifteen turbine-generator units and canal system from its license will require a decommissioning plan to define the final disposition of the canal system, turbine-generator units, water conveyance structures, and mechanical and electrical components. A decommissioning plan is also necessary to protect the public from any safety, dam safety, or environmental concerns. Boott will develop a decommissioning plan for each of the four downtown power stations and the canal system. In developing the decommissioning plan, Boott will consult with the NPS, MADCR, City of Lowell, and the Massachusetts Historical Commission (MHC). Boott will file a decommissioning plan for the Commission's approval within 18 months of issuance of a new license.

Fish Passage

- Boott proposes to replace the existing fish lift with a short fish ladder to pass migratory fish from the E.L. Field powerhouse tailrace to the bypass reach, such that all fish would be passed upstream of the Project via the existing fish ladder at the Pawtucket Dam. The Licensee will consult with the MRTC member agencies to determine the design and installation schedule for the proposed ladder.
- Following installation and operation of the fish ladder at the tailrace, Boott proposes to cease operations of the upstream fish elevator at the tailrace. The timing of cessation of operation of the upstream fish elevator will be determined based on consultation with the MRTC.
- Boott proposes to continue to work with the MRTC to identify any necessary minor modifications to the existing upstream fish ladder located at the Pawtucket Dam, and/or to the existing weirs in the bypass reach to improve passage.

[6] The Merrimack River Technical Committee is comprised of the following state and federal agencies: New Hampshire Department of Fish and Game (NHDFG), Massachusetts Division of Fisheries and Wildlife (MADFW), Massachusetts Division of Marine Fisheries (MADMF), United States Fish and Wildlife Service (USFWS), United States Forest Service (USFS), and National Marine Fisheries Service (NMFS).

- Boott proposes the installation of new trashracks or other fish exclusion facility at the E.L. Field Powerhouse which will be consistent with current USFWS passage guidelines, to prevent entrainment of fish through the turbines. Downstream passage of fish will continue to be provided via the existing sluice gate in the left forebay wall of the E.L. Field Powerhouse. The Licensee will consult with the MRTC member agencies to determine the design and installation schedule for the proposed fish exclusion system. Boott reserves the right to seasonally deploy the new trashracks or other exclusion facility only during the downstream fish passage season (mid-May – November), and to use the existing trashracks outside of the fish migration season.
- Boott proposes to develop a Fishways Operation and Management Plan in consultation with the MRTC. The proposed plan would effectively replace the Project's existing Comprehensive Fish Passage Plan.

Historic Properties

- Within one year of license issuance, Boott will develop a Historic Properties Management Plan (HPMP) for the Project that will describe appropriate management measures to avoid, minimize, or mitigate Project-related adverse effects on historic and archaeological resources over the term of the new license issued for the Project. The measures provided in the HPMP will direct the Licensee's management of NRHP-listed or eligible historic properties within the proposed Project boundary. Boott will develop the HPMP in consultation with the NPS, MHC, New Hampshire Division of Historic Resources (NHDHR), and Indian tribes.
- Boott proposes to continue to adhere to existing license Article 33, which requires that prior to the commencement of any construction activities inside the Project boundary, Boott will cooperate with the Massachusetts SHPO and the NPS to carry out a mitigation program for avoiding or minimizing adverse effects on the Locks and Canals Historic District and the Lowell National Historical Park.

Recreation

- Within one year of license issuance, Boott will develop a Recreation Access and Facilities Management Plan in consultation with the stakeholders to: a) evaluate opportunities for increasing pedestrian access to the Northern Canal Walkway under certain conditions; b) define flow management practices needed to enhance recreational opportunity in the project vicinity; and c) continue to manage the Project's recreation facility, the E.L. Field Powerhouse Visitor Center.

License Term

- In view of the substantial capital investment in new or improved fish passage facilities that Boott is committing to within this license application, Boott requests that the Commission issue the new license for a term of 50 years. This request is consistent with the Commission's 2017 Policy Statement on Establishing License Terms for Hydroelectric Projects,[7] which recognizes "significant measures expected to be

[7] PL17-3-000, October 19, 2017

required under the new license" when considering extension of a license term beyond the 40-year default period.

Boott notes that certain studies required by the Commission are ongoing (the Three-Dimensional CFD Modeling Study and the Whitewater Boating and Access Study). Boott will consult with stakeholders regarding the results and recommendations of these studies and potential PM&E measures. As appropriate, Boott may propose additional PM&E measures in a supplement to this license application.

E.7 Environmental Analysis by Resource Area

Pursuant to 18 C.F.R. § 5.18(b), this section discusses the existing Project related resources in more detail and analyzes the effects of the proposed action on these Project area resources. This section incorporates by reference all relevant prior relicensing materials including the resource study reports. The most important and relevant information from the reports and prior documentation are summarized herein as part of the analysis of the effects.

This section is divided into the following major resource areas:

- Geological and Soil Resources
- Water Quantity and Quality
- Fish and Aquatic Resources
- Terrestrial Resources
- Rare, Threatened, and Endangered (RTE) Species
- Recreation and Land Use
- Aesthetic and Socioeconomic Resources, and
- Cultural Resources

Each of the above resource areas is further divided into the following major subsections:

- Affected Environment - This subsection presents information on the affected environment using the information filed in the Licensee's PAD, information developed through the Licensee's FERC-approved study plans, and other information otherwise developed or obtained by the Licensee.
- Environmental Analysis - This subsection describes the beneficial and potential adverse effects of continued operation of the Project as proposed. Where appropriate, this subsection addresses both site-specific and cumulative Project effects, as required by Scoping Document 2 (SD2). The environmental analysis for each resource area is based on information presented in the PAD, the results of studies conducted in support of the license application, professional expertise, and other information obtained by the Licensee. This subsection also describes the Licensee's proposed environmental measures designed to address potential Project effects, and how the Licensee's proposed measures would protect or enhance the existing environment. The measures are listed above and described in greater detail in these subsections, as appropriate.
- Proposed environmental measures - This subsection describes any proposed new environmental measures, including, but not limited to, changes in the project design or operations, to address the environmental effects identified above and its basis for proposing the measures.
- Unavoidable Adverse Effects - This subsection describes any adverse impacts that would occur despite the Licensee's proposed environmental measures.

E.7.1 Geology and Soil Resources

The subsections below describe geology and soil resources in the vicinity of the Project and consider the effects of continued operation of the Project as proposed by the Licensee on geological and soil resources.

E.7.1.1 Affected Environment

E.7.1.1.1 Geology

Physiography and Topography

The Lowell Project is located in the New England Physiographic Province. This broad physiographic section is characterized as a mountainous area of significant relief. The area is made up of highly deformed Precambrian and Paleozoic metamorphic rocks, including gneiss, schist, slate, quartzite, and marble. The province was glaciated during the Pleistocene and shows both depositional and erosional effects of glacial ice. The Taconic, Green, and White Mountain ranges are distinct features of the New England Physiographic Province. The Taconic Mountains are a north-south trending mountain range along the western edge of the province and are thought to be formed by erosion of an upper block of a large thrust fault. Also, trending north south, the Green Mountains exist primarily in Vermont and are made of Precambrian gneisses. The White Mountains are an exhumed mass of Paleozoic granite and include Mount Washington in New Hampshire, the tallest mountain in the region at 6,288 feet. The province is valued for its mineral resources, both industrial and as building materials. Marble, granite, and slate are all widely distributed and quarried within the province (NPS undated *a*).

The Merrimack River watershed traverses each of the three major sections of the New England Physiographic Province: the White Mountains, New England Uplands, and Seaboard Lowlands (Flanagan et al. 1999 as cited in USACE 2003). The majority of the basin falls within the New England Uplands region, which is characterized by rolling hills and has a local relief ranging from a few hundred feet to 1,000 feet in more mountainous regions. The watershed elevation ranges from a high of 5,249 feet on Mount Lafayette in the White Mountain region to mean sea level along the northeastern Massachusetts coast (USACE 2003).

The Lowell Project is located in the Seaboard Lowlands Section of the New England Physiographic Province. The Seaboard Lowlands Section is lower in elevation and less hilly than the New England Upland Section. The boundary between these two sections is between 400 and 500 feet in elevation in most places. According to Flanagan et al. (1999), topographic relief in the Seaboard Lowlands Section is limited to less than approximately 200 feet in most places. In the vicinity of the Project, the Merrimack River flows through a region of rapid population growth and development that is heavily influenced by the Lowell metropolitan area. The local relief in the Merrimack River Valley in the Project vicinity is generally characterized as low, open hills. A topographic map of the Project and vicinity is presented in Figure E.7-1 through Figure E.7-5.

Figure E.7-1. Lowell Project Topographic Map Showing Proposed Project Boundary

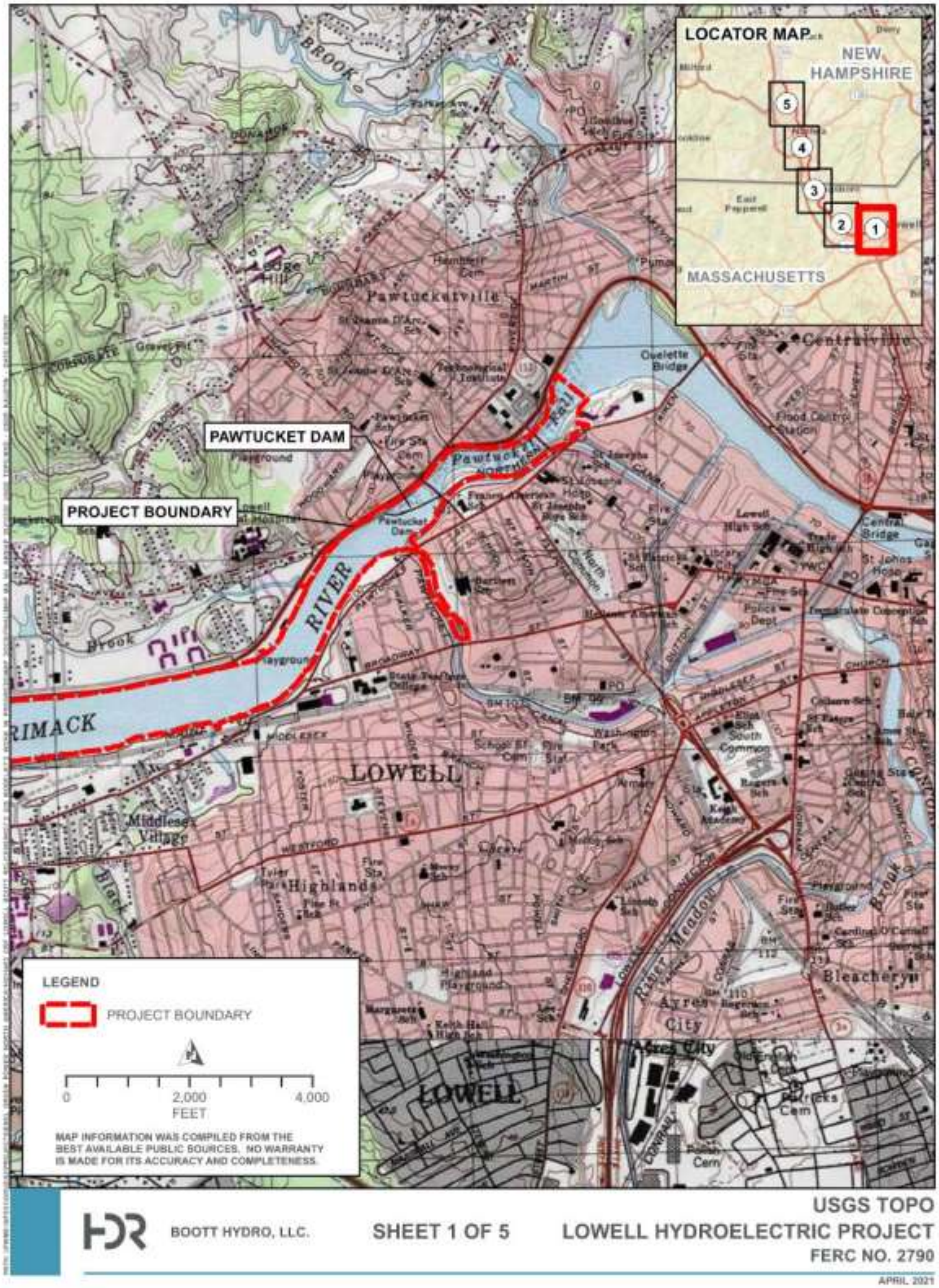


Figure E.7-2. Lowell Project Topographic Map Showing Proposed Project Boundary

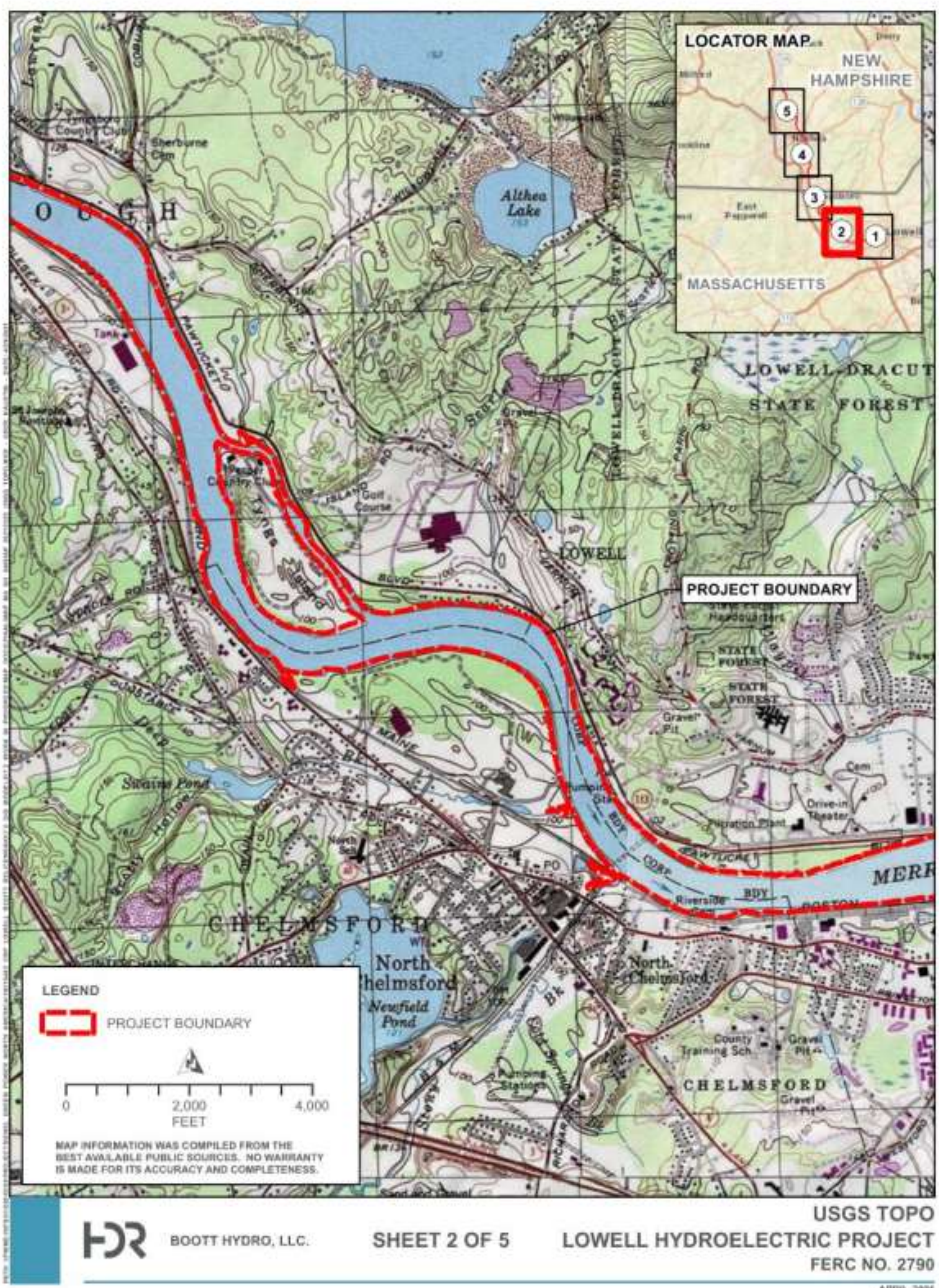


Figure E.7-3. Lowell Project Topographic Map Showing Proposed Project Boundary

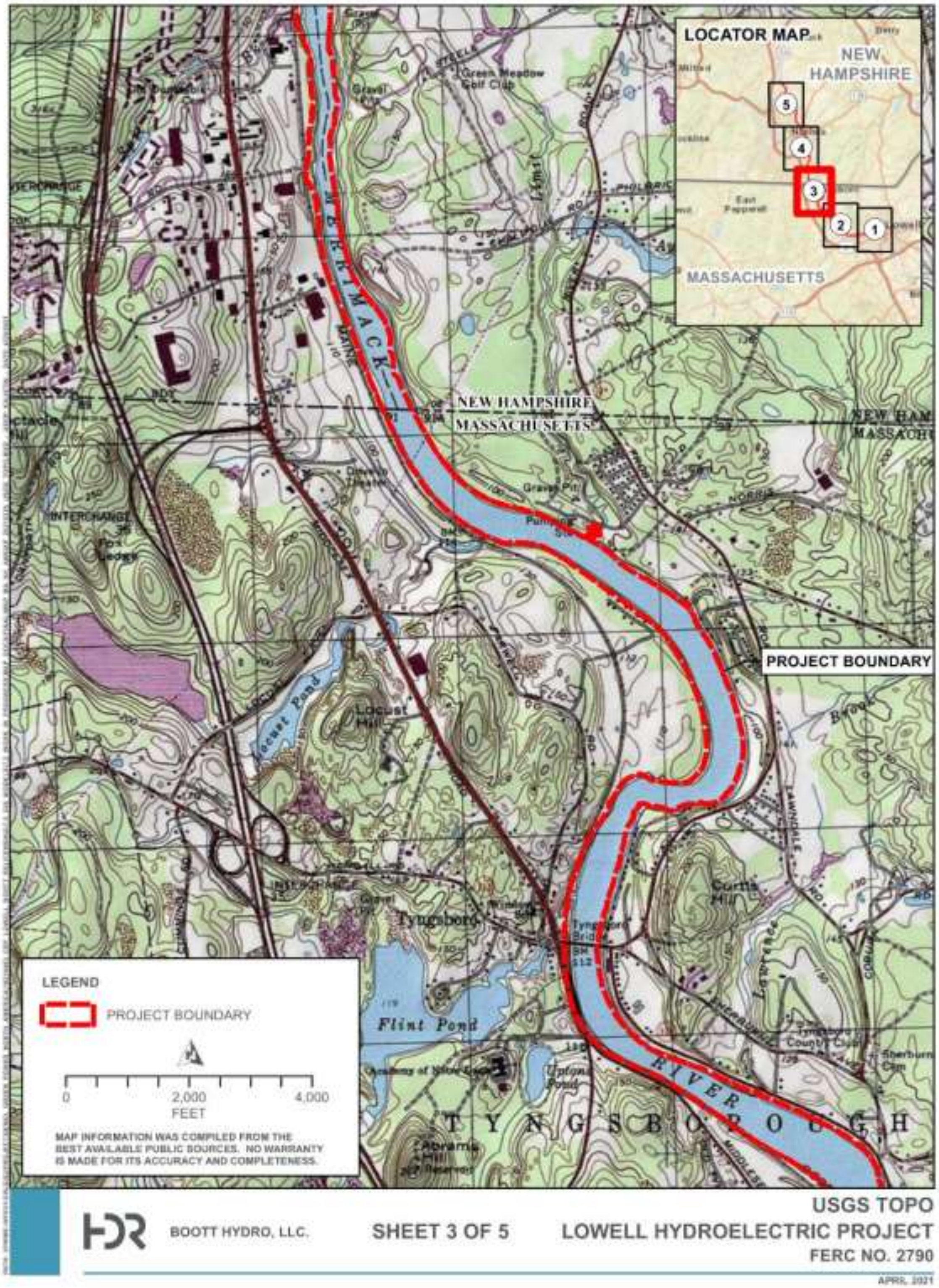


Figure E.7-4. Lowell Project Topographic Map Showing Proposed Project Boundary

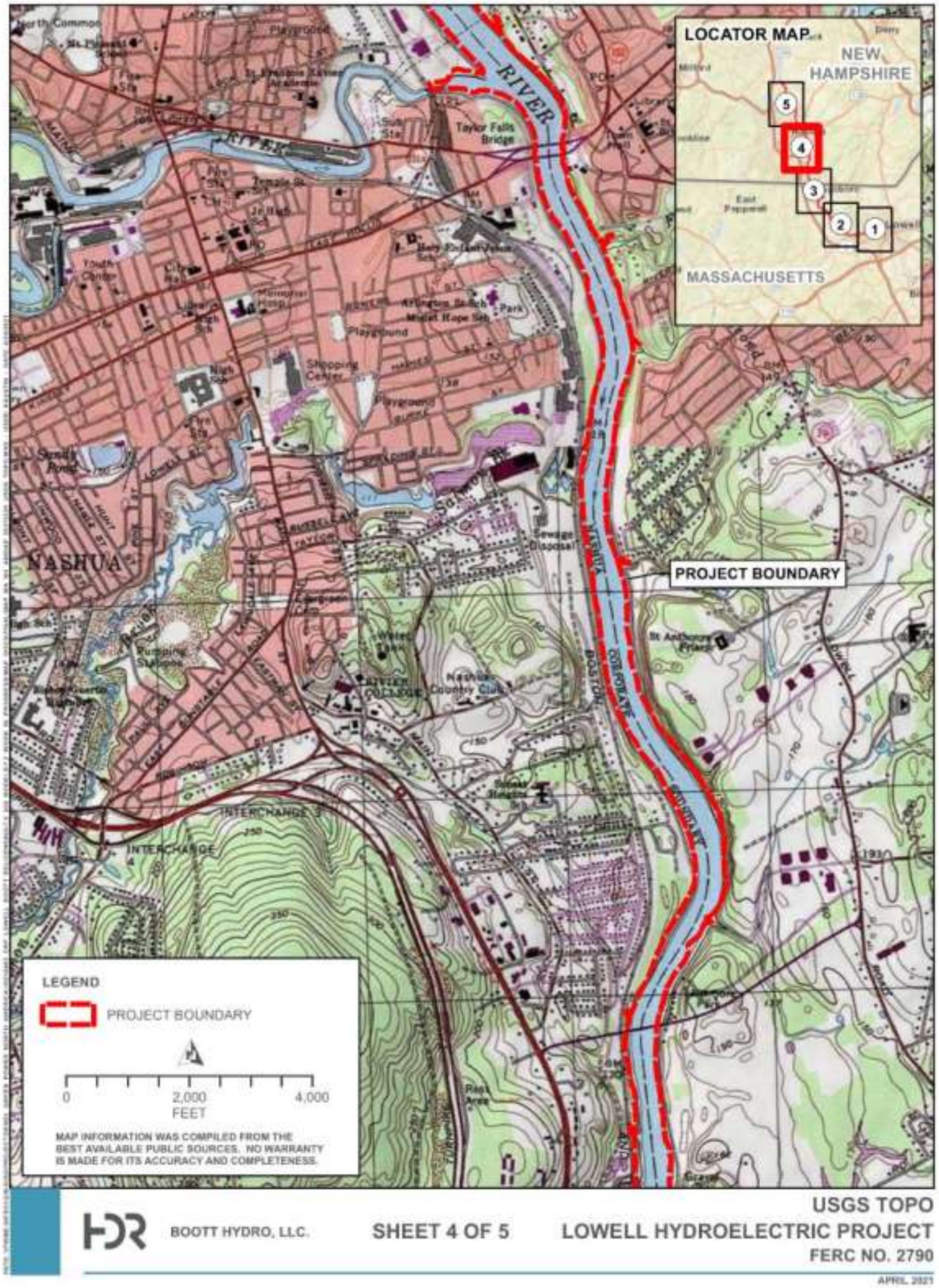
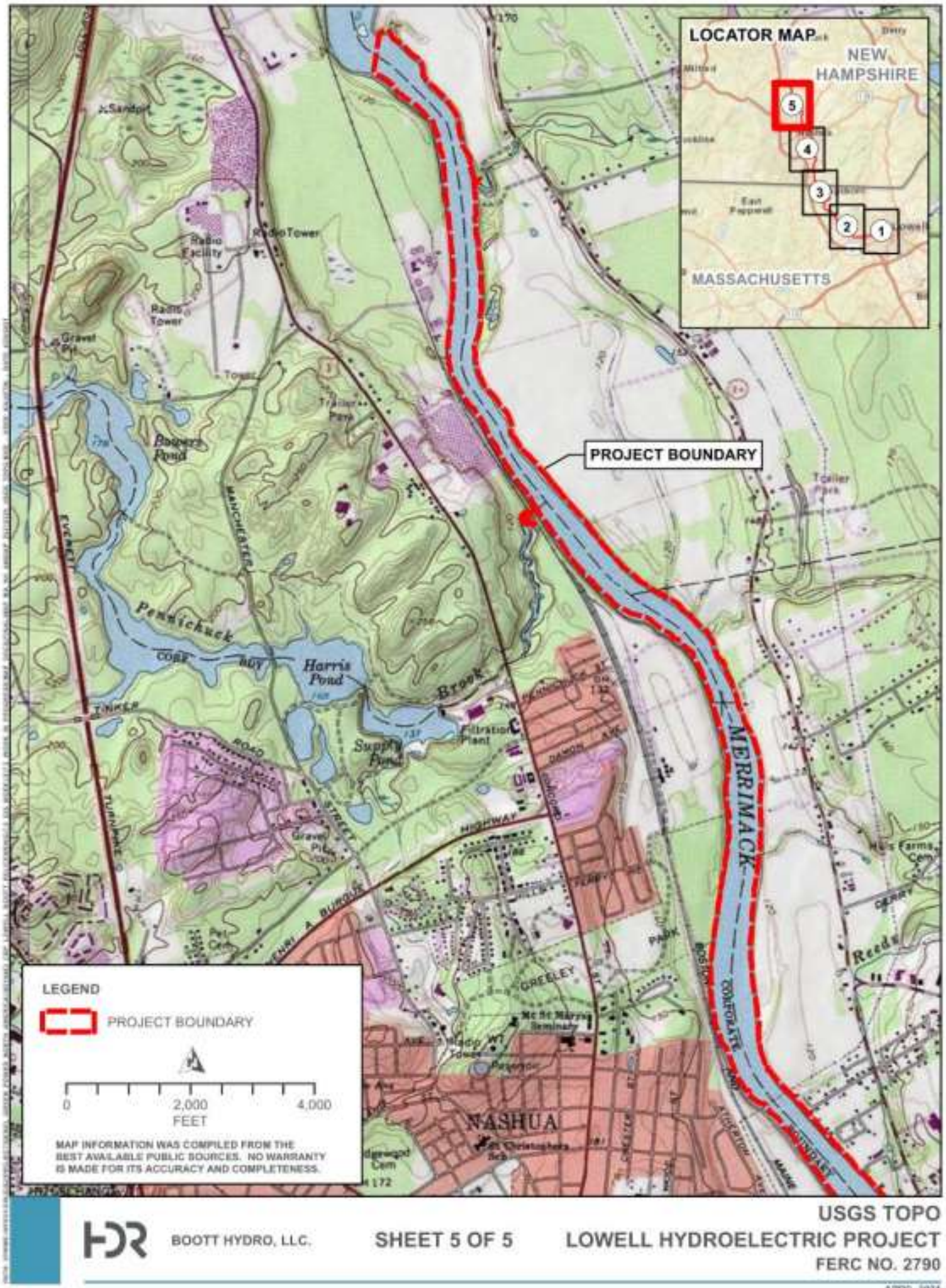


Figure E.7-5. Lowell Project Topographic Map Showing Proposed Project Boundary



Bedrock Geology

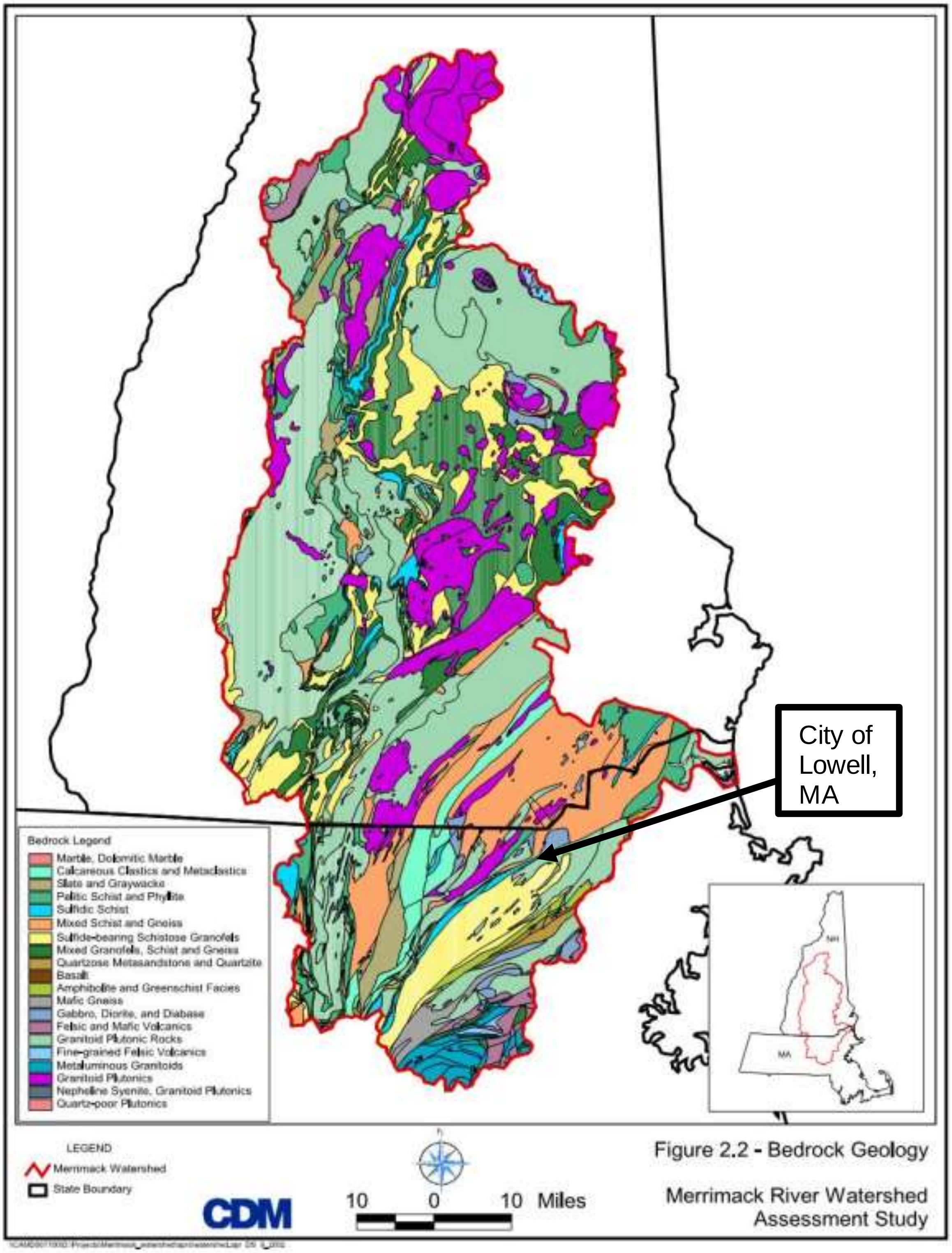
Bedrock in the Merrimack River watershed is generally of similar age and genesis. Intrusive igneous rocks, primarily Granitoid Plutonic rocks, dominate the northeastern portion of the river basin. Large deposits of metamorphic mixed and sulfide-bearing granofels cover the north-central and northwestern portion of the basin. A strip of metamorphic grade rocks, including mixed schist and gneiss deposits, cuts across the Massachusetts-New Hampshire border in a northeasterly direction (USACE 2003). The bedrock is generally layered and complexly deformed. Structures and contacts generally trend northeast to southwest, perpendicular to the direction of collision during the Acadian Orogeny. The mineralogy of the bedrock units is highly varied, from pure quartz in quartzite formations to thin layers of calc-silicate rocks, large bodies of schist with various mineral assemblages (often with high iron and manganese concentrations), and metavolcanics with high base-cation concentrations (Flanagan et al. 1999).

The Merrimack Quartzite is the principal bedrock unit underlying the Project. Although the rock is cut by abundant fractures, it is hard and relatively unweathered. The low-grade metasedimentary rock is of Silurian or Devonian age, approximately 400 million years old. Lithologically, the rock is a fine-grained, impure, bedded quartzite with minor schist. In places, quartzite consists of alternating coarse-grained sandy beds with silty beds (Boott 2015).

The Project is also nearby the mapped contact between the Merrimack Quartzite and the Ayer Granite. The Ayer Granite is a late Paleozoic intrusion. It is a complex igneous rock with an average composition of granodiorite. It is a light- to medium-gray, medium- to coarse-grained rock, commonly porphyritic, gneissic or migmatitic (Boott 2015).

A bedrock geology map of the Merrimack River watershed is presented in Figure E.7-6.

Figure E.7-6. Merrimack River Watershed Bedrock Geology



Source: USACE 2002

Surficial Geology

Glaciation has shaped the landscape of eastern North America during several major glacial periods. As glaciers flowed across the landscape, they scraped and sculpted the land surface. As glaciers retreated from the landscape during deglaciation, they created lakes and altered the course of rivers. Debris scraped off the land surface was carried by the ice and deposited as sand, gravel, and other unconsolidated sediments across the landscape. Some of the sediments were deposited by the ice directly, and the rest were carried by meltwater streams and deposited in the sea or elsewhere on land. Most of the surficial sediments found across New England are a result of glaciation (Flanagan et al. 1999).

The Merrimack River basin is generally covered by a sheet of glacial till, with areas of large fine- and large-grained, glacial-lake deposits along the river mainstem and major tributaries (Flanagan et al. 1999 as cited in USACE 2003). Till, known locally as "hardpan," is composed of boulders, gravel, sand, silt, and clay mixed in various proportions, and is usually compact, stony, and difficult to dig. Lodgement (or basal) till, deposited directly beneath active ice, is generally more compact than ablation till (Flanagan et al. 1999).

According to the USACE (1977), the till cover within the Merrimack River basin is composed of variable, unstratified, silty, gravelly, sand and clays. The cover is generally thin on the hilltops and in the deep valleys, with exposed bedrock typically visible in the hilly upland regions. Large glacial melt-water lakes formed throughout the basin during glacial retreat (USACE 2003).

Mineral Resources

As mentioned above, the New England Physiographic Province is valued for its mineral resources, both industrial and as building materials. Marble, granite, and slate are all widely distributed and quarried within the province (NPS undated *a*). There are no mapped oil, gas, or mineral resources in the Lowell Project boundary. According to the USGS (USGS Undated *a*), there are three active mines in the Project vicinity, including the Westford Quarry located approximately 4.5 miles southwest of Pawtucket Dam, the Chelmsford Quarry located approximately 4.4 miles southwest of Pawtucket Dam, and a Sand and Gravel Operation located approximately 5.4 miles northeast of Pawtucket Dam in Essex County, MA.

E.7.1.1.2 Soils

Soil types in the vicinity of the Lowell Project are variable and reflect the diversity of parent materials, the local topography, and the physiographic position of landforms. The Project vicinity is composed of soil series formed primarily in glacial and glaciofluvial deposits, sandy outwash or eolian deposits, and recent alluvium. According to USACE (2003), soil types occurring in the vicinity of the Project include silt loam, unweathered bedrock, loamy sand, and areas mapped as mucky peat. Additionally, a large portion of the soils mapped in the Project vicinity are classified as Udorthents. There are many types of Udorthent soils, but in general they include areas of human altered soil and non-soil areas that are mapped based on their surface texture, type of alteration, depth to water table, and geologic setting. Some human-altered map units include sand, gravel, till, quarry pits, areas of excavated (cut and fill) geologic material, and areas used for the disposal of refuse.

Mapped soils in the vicinity of the Project are presented in Figure E.7-7 through Figure E.7-8. A 100-foot buffer has been applied to the Project boundary to develop this figure. Map unit delineation on a soil map represents an area that is dominated by one or more major kinds of soil or miscellaneous area. Each map unit is identified, and names are in accordance with the taxonomic classification of the dominant soils. The U.S. Department of Agriculture's (USDA) Official Soil Series Descriptions for mapped soil series Figure E.7-7 through Figure E.7-8 are presented in Appendix A of this FLA (USDA undated).

E.7.1.1.3 Impoundment Shoreline and Stream Banks

The shoreline surrounding the Merrimack River within the Project area typically consists of low-to-moderate slopes dominated by urban, commercial, industrial, and residential development. Some areas along the shoreline within the Project vicinity consist of agricultural areas and some areas consist of forest canopy vegetation underlain by established shrub and herbaceous layers. Large boulders, cobbles, or exposed bedrock are uncommon along the shoreline of the Merrimack River within the Project area. A portion of the shoreline is bordered by walking trails which are used by the public, and the majority of the southern shoreline is bordered by a railroad.

A summary description of the streambanks for the Merrimack River within the Project area in the vicinity of the Project is provided below based on the results of the Recreation and Aesthetics Study performed by Boott in 2020 (HDR 2021a).

A wide variety of vegetation types, occurrences, and distribution, ranging from herbaceous, non-woody plants to forested areas of trees and underbrush, and shoreline/canal types, ranging from earthen embankments to placed, uniformly sized blocks were observed during the study. Mapped vegetation was greatest in the Pawtucket Canal, followed by the Eastern Canal, Western Canal, and Northern Canal. Common vegetation species observed along the canals and within the Project area along the Merrimack River include tree of heaven (*Ailanthus altissima*), American elm (*Ulmus americana*), silver maple (*Acer saccharinum*), red maple (*A. rubrum*), Siberian elm (*Ulmus pumila*), various goldenrod (*Solidago*) species, and some weedy and invasive species including purple loosestrife (*Lythrum salicaria*), poison ivy (*Toxicodendron radicans*), Boston ivy (*Parthenocissus tricuspidata*), mullein (*Verbascum thapsus*), and common ragweed (*Ambrosia artemisiifolia*).

There is no evidence of erosion, slumping, or slope instability around the shoreline of the Project.

E.7.1.1.4 Seismicity

The northeast United States lies within the relatively tectonically stable and geologically old North American plate, where a great deal of the tectonic action took place over 200 million years ago when the Atlantic basin began to form due to the separation of Africa from North America. However, based on instrumental seismic records, earth scientists believe that the tectonic activity in the northeast is still ongoing (Ebel 1987).

The Project is located in Seismic Zone 2 and is subject to earthquakes of moderate intensity. The Clinton-Newbury fault zone forms an important regional crustal plate boundary and is located roughly 1.5 miles southeast of the Project area. No recent largescale earth movements are known along the Clinton-Newbury fault and it is considered inactive (Boott 2015).

Regarding historic seismicity, the USGS National Earthquake Information Center Database was searched regarding earthquakes within the Project region from 1970 to present day. The most significant (largest and closest) events were indicated by the USGS to be a magnitude (M) of 3.7 on October 2, 1994, 54 miles from the Project, and a M of 3.1 on January 10, 1999, 22.3 miles from the Project (USGS undated *b*).

E.7.1.2 Environmental Analysis

No potential issues related to geological or soil resources were identified during the scoping process. There are currently no adverse Project effects on geology or soils, and Boott is not proposing major operational changes to the Project. Continued operation of the Project is not expected to have a material adverse effect on geologic resources, soils, or the geomorphology of the Project impoundment.

E.7.1.3 Proposed Environmental Measures

Boott proposes continued operation of the Project with certain PM&E consistent with the measures required by the Project's existing license.

E.7.1.4 Unavoidable Adverse Impacts

Unavoidable adverse impacts are those effects that may still occur after implementation of PM&E measures. Continued Project operations as proposed by the Licensee are not expected to have any unavoidable adverse impacts on geological or soils resources.

Figure E.7-7. Lowell Project Soils Map Showing Proposed Project Boundary

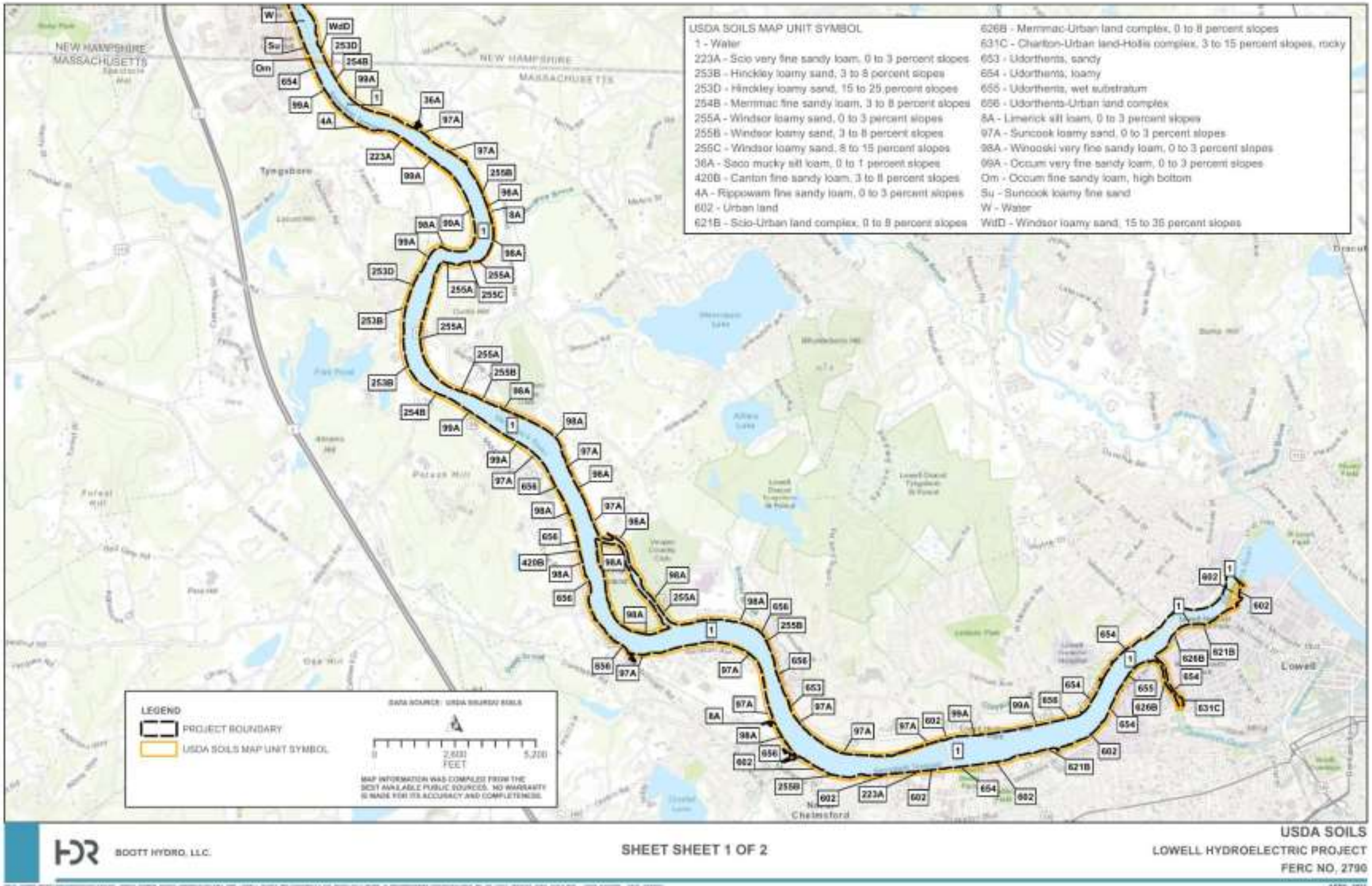
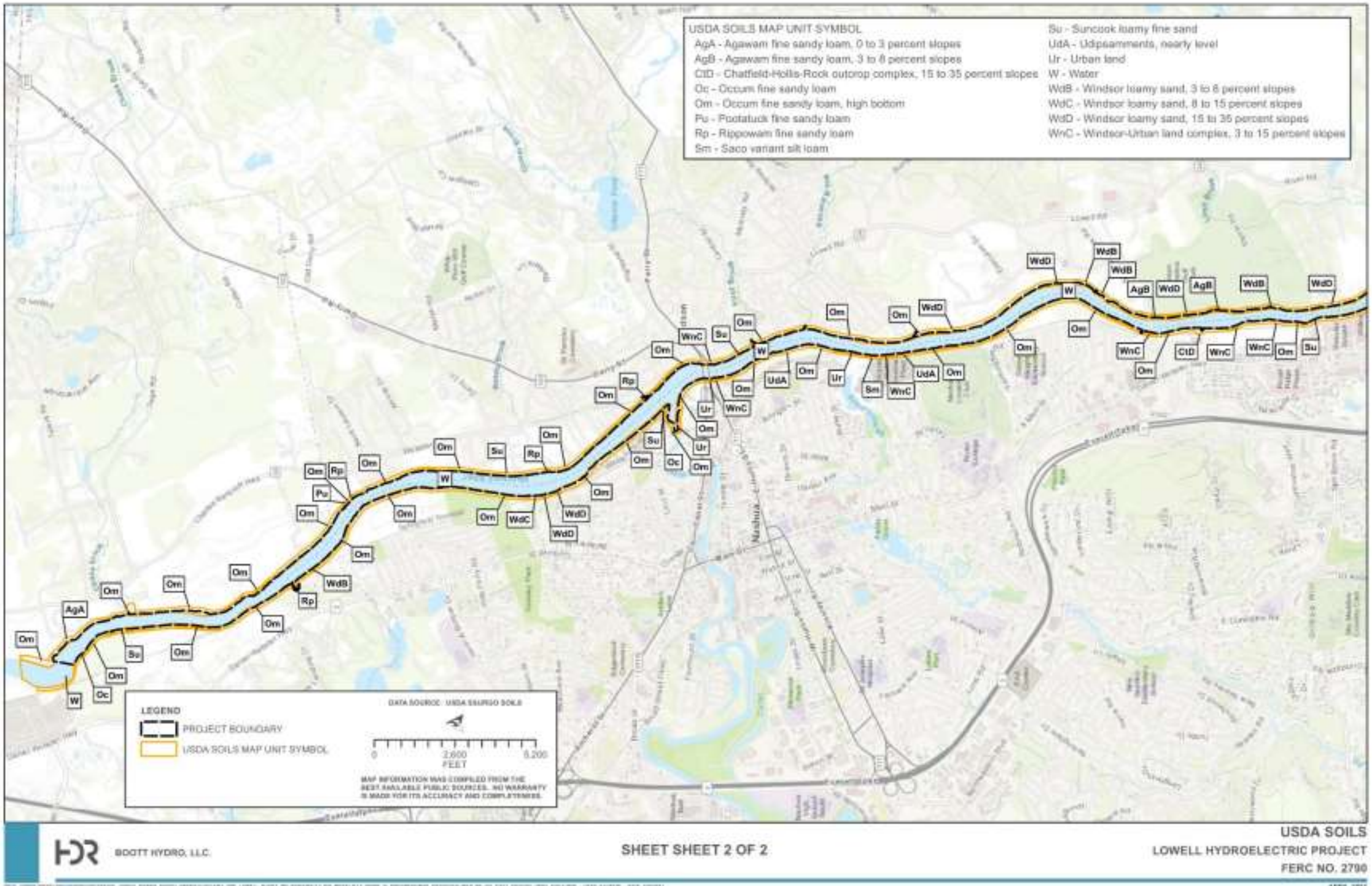


Figure E.7-8. Lowell Project Soils Map Showing Proposed Project Boundary



E.7.2 Water Quantity and Quality

The subsections below describe water resources in the vicinity of the Project and consider the effects of continued operation of the Project as proposed by the Licensee on water quantity and quality. Descriptions of the affected environment, the environmental analysis, the proposed environmental measures, and the identification of unavoidable adverse effects were developed based on available data presented in the Licensee's PAD and water resources data collected from:

- Downstream American Eel Passage Assessment (Normandeau Associates, Inc [NAI] 2021a)
- Fish Assemblage Study (NAI 2021d)

These reports are included in Appendix B of this exhibit.

E.7.2.1 Affected Environment

E.7.2.1.1 Water Quantity

The Merrimack River watershed has a total drainage area of approximately 5,010 square miles within the states of New Hampshire and Massachusetts (Massachusetts Executive Office of Energy and Environmental Affairs [MEOEEA] 2002). The Lowell Project is located at river mile (RM) 41 on the Merrimack River in Massachusetts with an existing impoundment extending upstream approximately 16miles to Cromwell's Falls in Merrimack and Litchfield, New Hampshire.[8] The drainage area of the Project is approximately 3,979 square miles.

E.7.2.1.2 Project Hydrology

The Project operates in a run of river (ROR) mode, and therefore, experiences seasonal and annual variations in flows based on natural hydrologic conditions in the Merrimack River Watershed. Table E.7-1 provides Project hydrologic data from 1987-2016.

Table E.7-1. Lowell Project Hydrologic Data (1987-2016)

Month	Minimum (cfs)	90% Exceedance (cfs)	Average (cfs)	10% Exceedance (cfs)	Maximum (cfs)
January	916	3,462	7,651	12,834	39,710
February	1,478	3,272	6,813	11,415	39,180
March	1,914	4,508	11,484	21,355	50,220
April	2,765	6,558	17,901	31,178	78,890

[8] The preparation of Exhibit G boundary maps provided Boott the opportunity to make corrections and modifications consistent with the Project's operations. Boott is proposing to remove about 7.4 miles from the upper limit of the current Project boundary, making the proposed Project impoundment about 16 miles in length. This removal more accurately follows the 92.2 NGVD 29 contour of the Project impoundment. See Exhibit G.

Month	Minimum (cfs)	90% Exceedance (cfs)	Average (cfs)	10% Exceedance (cfs)	Maximum (cfs)
May	2,034	4,112	10,749	18,657	88,410
June	874	2,279	6,768	13,286	44,660
July	670	1,325	4,207	9,270	29,820
August	569	1,121	3,526	6,852	30,030
September	460	1,008	3,162	6,025	32,264
October	787	1,676	5,938	12,706	50,150
November	1,345	2,888	7,978	14,747	30,990
December	1,839	3,472	9,141	17,243	34,810
Annual	460	1,723	7,941	17,059	88,410

Note: Project hydrology determined by subtracting flows from USGS Gage No. 01099500 (*Concord River Below Meadow Brook, at Lowell, MA*) from USGS Gage No. 01100000 (*Merrimack River Below Concord River at Lowell, MA*).

Existing Instream Flow Uses

Existing instream flow uses of the Merrimack River include hydropower generation and industrial uses with recreation (e.g., fishing and boating). There are five FERC-regulated hydroelectric projects on the Merrimack River, and another two located on the main stem Pemigewasset River. The Project is located approximately 11 miles upstream of the Lawrence Hydroelectric Project (FERC No. 2800) and approximately 30 miles downstream of the Amoskeag Dam (one of the three developments of the Merrimack River Project, FERC No. 1893) in New Hampshire. There are also four U.S. Army Corps of Engineers (USACE) flood storage dams within the Merrimack River basin.

Existing and Proposed Uses of Project Waters

In Massachusetts, the Massachusetts Department of Environmental Protection (MADEP) regulates the quantity of water withdrawn from both surface and groundwater supplies to ensure adequate water supplies for current and future water needs pursuant the Massachusetts Water Management Act (MADEP 2018a). Available registrations and permits were reviewed. Two regulated water withdrawals were identified in Lowell. These withdrawal users were identified as Lowell Water Treatment Facility (Permit #9P231316003) and Western Avenue Dyers (Permit #9P131316001). Based on the 2016-2019 Annual Water Quality Reports by the Lowell Regional Water Utility (LRWU), the utility withdrew 3.9 to 4.2 billion gallons of water from the Merrimack River annually to provide drinking water for Lowell and the surrounding communities (LRWU 2016, 2017, 2018, 2019).

In New Hampshire, Pennichuck Water Works supplies water for the City of Nashua and 10 surrounding New Hampshire municipalities located in southern New Hampshire, using both surface water and groundwater sources. The Nashua Core water system derives its water supply from the Pennichuck Brook and the Merrimack River watersheds (Pennichuck Water Works 2018). The city of Manchester currently does not utilize the Merrimack River as a drinking water source, but it is anticipated to by year 2022 (Manchester Water Works 2019).

In New Hampshire, the New Hampshire Department of Environmental Services (NHDES) regulates large groundwater withdrawals under the state's Groundwater Protection Act to ensure that no adverse impacts to water users or natural resources occur as a result of withdrawals (NHDES 2018). The only two groundwater withdrawal permits within the Project vicinity were issued to the Merrimack Village District Water Works in New Hampshire (Permittee Number LGWP-2017-0001) for 432,000 gallons per day and to Manchester Water Works (Permittee Number LGWP-2020-0001) for 7.2 million gallons per day. However, neither permit holder has started withdrawing from the permitted source (NHDES 2020).

The U.S. Environmental Protection Agency (USEPA) is the permitting authority in Massachusetts and New Hampshire for issuing National Pollutant Discharge Elimination System (NPDES) permits, which are required whenever a municipality, industry, or other entity wishes to discharge pollutants to a surface water of the United States. In Massachusetts, NPDES permits are typically co-issued by the USEPA and MADEP (MADEP 2018b). Available NPDES permits were reviewed for the Project vicinity in Massachusetts (Commonwealth of Massachusetts 2020a, USEPA 2018). The only permit located within the Project area was issued to the City of Lowell for Combined Sewer Overflow (CSO) outfalls at 9 locations, 7 of which are discharged into the main stem of the Merrimack River, and one of these outfalls is located just upstream of the Pawtucket Dam. The other two outfalls discharge in Beaver Brook and the Concord River, which are both tributaries to the Merrimack River just downstream from the Pawtucket Dam (USEPA 2019a).

Three NPDES permits were identified within the Project vicinity in New Hampshire, which were issued for wastewater treatment facilities and combined sewer overflows to the city of Manchester (Permit Number NH0100447), the town of Merrimack (Permit Number NH0100161) and the city of Nashua (Permit Number NH0100170) (USEPA 2020a). Another permit was issued to Nylon Corporation of America in Manchester for two separate outfalls (USEPA 2019b).

The Lowell Project has four NPDES permits issued under the Massachusetts General Permit no. MAG360000. These are: Permit No. MAG360024 for the Eldred L. Field Powerhouse; No. MAG360026 for the Hamilton powerhouse; No. MAG360025 for the John St. powerhouse; and No. MAG360027 for the Section 8 powerhouse.

E.7.2.1.3 Water Quality

Massachusetts Water Quality Standards

Water quality standards for the Commonwealth are contained in the Code of Massachusetts Regulations (CMR) at 314 CMR 4.00: Massachusetts Surface Water Quality Standards (SWQS). Inland surface waters of the Commonwealth are classified by appropriate use Class (A, B, or C) as defined in 314 CMR 4.05. Qualifiers applied to these classifications indicate special considerations and uses applicable to a waterbody segment that may affect the application of criteria or antidegradation provisions. The classification of surface water in Massachusetts is provided in 314 CMR 4.06.

The MADEP's Division of Water Pollution Control has classified waters within the Project vicinity as Class B with specific qualifiers (Table E.7-2). As defined in 314 CMR 4.05(3)(b), Class B waters are designated as:

> *[A] habitat for fish, other aquatic life, and wildlife, including for their reproduction, migration, growth, and other critical functions, and for primary and secondary contact recreation. Where designated in 314 CMR 4.06, Class B waters shall be suitable as a source of public water supply with appropriate treatment ("Treated Water Supply"). Class B waters shall be suitable for irrigation and other agricultural uses and for compatible industrial cooling and process uses. These waters shall have consistently good aesthetic value.*

A summary of the standards applicable to Class B waters with the Warm Water qualifier is provided in Table E.7-3.

Table E.7-2. Water Quality Classification Applicable to the Lowell Project in Massachusetts

Boundary	Mile Points	Class	Qualifiers
State line to Pawtucket Dam	49.8 – 40.6	B	Warm Water[1] Treated Water Supply[2] CSO[3]
Pawtucket Dam to Essex Dam, Lawrence	40.6 – 29.0	B	Warm Water[1] Treated Water Supply[2] CSO[3]

Source: 314 CMR 4.06.

[1] In these waters, dissolved oxygen and temperature criteria for warm water fisheries apply.

[2] Denotes those Class B waters that are used as a source of public water supply after appropriate treatment. These waters may be subject to more stringent site-specific criteria established by the Department as appropriate to protect and maintain the use. See, also, 310 CMR 22.00.

[3] These waters are identified as impacted by the discharge of combined sewer overflows (CSO); however, a long-term control plan has not been approved or fully implemented for CSO discharges.

Table E.7-3. Water Quality Standards for Class B Waters with the Warm Water Qualifier in Massachusetts

Parameter	Class B Warm Water Standards
Dissolved Oxygen (DO)	Shall not be less than 5.0 milligrams per liter (mg/L) in warm water fisheries. Where natural background conditions are lower, DO shall not be less than natural background conditions. Natural seasonal and daily variations that are necessary to protect existing and designated uses shall be maintained.

Parameter	Class B Warm Water Standards
Temperature	Shall not exceed 83 degrees Fahrenheit (°F) (28.3 degrees Celsius [°C]) in warm water fisheries. The rise in temperature due to a discharge shall not exceed 5°F (2.8°C) in rivers and streams designated as warm water fisheries (based on the minimum expected flow for the month). Natural seasonal and daily variations that are necessary to protect existing and designated uses shall be maintained. There shall be no changes from natural background conditions that would impair any use assigned to this Class, including those conditions necessary to protect normal species diversity, successful migration, reproductive functions, or growth of aquatic organisms.
pH	Shall be in the range of 6.5 through 8.3 standard units and not more than 0.5 units outside of the natural background range. There shall be no change from natural background conditions that would impair any use assigned to this Class.
Color and Turbidity	These waters shall be free from color and turbidity in concentrations or combinations that are aesthetically objectionable or would impair any use assigned to this Class.

Source: 314 CMR 4.05.

New Hampshire Water Quality Standards

Water quality standards in New Hampshire are contained in New Hampshire's Revised Statutes Annotated (RSA) 485A:8, Standards for Classification of Surface Waters of the State, and in Env-Wq 1700, the Surface Water Quality Standards. RSA 485A:8 establishes that all New Hampshire surface waters must be classified as either Class A or Class B waters and establishes certain minimum surface water quality criteria for each classification (NHDES 2019b). The Merrimack River is designated as a Class B in New Hampshire, which pursuant to RSA 485A:8 shall be considered acceptable for fishing, swimming, and other recreational purposes and, after adequate treatment, for use as water supplies. A summary of the applicable standards to Class B is provided in Table E.7-4.

Table E.7-4. Water Quality Standards for Class B Waters in New Hampshire

Parameter	Class B Warm Water Standards
DO	Except as naturally occurs, waters shall have a DO concentration of at least 75% of saturation based on a daily average and an instantaneous minimum DO concentration of at least 5 mg/L.
Temperature	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.
pH	Shall be 6.5 to 8.0 unless due to natural causes.
Turbidity	Shall not exceed naturally occurring conditions by more than 10 Nephelometric Turbidity Units (NTUs).

Parameter	Class B Warm Water Standards
Color	Shall contain no color in such concentrations that would impair any existing or designated uses, unless naturally occurring.

E.7.2.1.4 Existing Water Quality Data

Water quality data have been collected throughout the Project area including: (1) in the Project's impoundment and bypassed reach in support of recent relicensing activities, (2) at a USGS gage just downstream from the Pawtucket Dam, (3) at three NHDES monitoring sites in the Project impoundment, and (4) at numerous sites from RM 29.6 to 55.9 by a volunteer monitoring program established by the Merrimack River Watershed Council.

Relicensing Study Data

In support of relicensing the Project, water quality data were collected in the Project's impoundment and bypassed reach during the Fish Assemblage Study (NAI 2021d) in the spring, summer, and fall of 2019. Water temperature, dissolved oxygen, conductivity, and pH data were collected at 12 locations throughout the impoundment and at three locations[9] throughout the bypassed reach. Turbidity data was also collected at the impoundment site locations, which trended towards shallower at the upper end of the reach upstream of the Pawtucket Dam in areas classified as pool and run, and deeper at the lower end in areas classified as impoundment. Sampling in the impoundment was conducted at a depth of approximately one meter. Sampling in the Project's bypass reach was conducted during low flows. All data collected in the impoundment and bypassed reach met state water quality standards.

In the impoundment, the average water temperature was 21.5°C (20.6-22.1°C) during the spring sampling, 25.6°C (25.2-26.0°C) during the summer sampling, and 10.8°C (10.3-11.5°C) during the fall sampling (Table E.7-5). The average dissolved oxygen concentration was 8.7 mg/L (8.4-9.0 mg/L) during the spring sampling, 8.4 mg/L (8.1-8.8 mg/L) during the summer sampling, and 10.6 mg/L (9.8-11.1 mg/L) during the fall sampling. Conductivity averaged 114 microsiemens per centimeter (µs/cm) (97-139 µs/cm) during the spring sampling, 181 µs/cm (166-199 µs/cm) during the summer sampling, and 117 µs/cm (91-152 µs/cm) during the fall sampling. The pH ranged from 6.5-7.5 units and turbidity ranged from 0.8-3.7 NTUs.

In the bypassed reach, data were only obtained at one location in the spring where the water temperature averaged 22.9°C, dissolved oxygen concentration was 9.5 mg/L, conductivity was 148 µS/cm, and the pH was 6.5 units (Table E.7-5). The average water temperature was 23.8°C (23.4-24.1°C) in the summer and 13.1°C (13.0-13.2°C) in the fall. The average dissolved oxygen concentration was 9.4 mg/L (9.1-9.6 mg/L) in the summer and 9.8 mg/L (8.9-10.6 mg/L) in the fall. Conductivity averaged 194 µS/cm (191-197 µS/cm) in the summer and 100 µS/cm (95-104 µS/cm) in the fall. The pH ranged

[9] Water quality data were only obtained from one location in the spring.

from 6.3-8.1 units, with the average river pH in the bypassed reach being higher during the summer (7.8 units) than was observed during the spring (6.5) or fall (6.6.).

Continuous water temperature data was also collected at the Project's intake canal from October 9, 2019 until November 31, 2019 during the Downstream American Eel Passage Assessment (NAI 2021a). Water temperatures ranged from 2°C to 16°C and were below the state of Massachusetts's maximum temperature criterion.

USGS Gage Data

The USGS periodically collected water quality data approximately 1.6 RM downstream from the Project powerhouse at gage 01100000 (Merrimack River BL Concord River at Lowell, MA) between 1953 and 2004 (USGS 2018), Figure E.7-9. The most recent data are presented in figures below, which consists of water temperature, DO, pH, and specific conductance data collected between 1998-2004 (Figure E.7-10 through Figure E.7-14). Data were collected at numerous times during the summer, often when temperatures are the highest and DO concentrations are the lowest, except in 1998. Water temperatures were seasonal and were below the state of Massachusetts's maximum temperature criterion. DO concentrations were well above the state minimum criterion of 5.0 mg/L and were near saturation, except on one occasion in August 1999. The pH met state standards, except on a single sampling event in December 2003 when it was 6.3 units. Specific conductance ranged from 83 to 328 µS/cm (USGS 2018).

Merrimack River Watershed Council Data

A volunteer monitoring program established by the Merrimack River Watershed Council (MRWC) collected water quality data at 41 monitoring stations located along the mainstem of the Merrimack River in 2009 (MRWC 2010). Results were grouped into one of the five river segments identified during the study. Results from three sections, including from the Essex Dam to the Pawtucket Dam in Lowell (Section 3), from the Pawtucket Dam to the Massachusetts/New Hampshire state border (Section 4), and from the state border to Greeley Park in Nashua (Section 5), are presented in Table E.7-6 through Table E.7-8. Nine sites were sampled in Section 3, eight sites were sampled in Section 4, and seven sites were sampled in Section 5. Monitoring occurred periodically between May and October in 2009, which included sampling during the summer months. Water temperatures ranged from 8.1 to 25.7°C and were below the maximum temperature criterion in Massachusetts of 28.3°C. DO concentrations ranged from 7.2 mg/L to 12.1 mg/L and were well above the Massachusetts and New Hampshire minimum state criterion of 5.0 mg/L. The pH was frequently below the acceptable minimum Massachusetts and New Hampshire criterion of 6.5 units and ranged from 3.3 to 6.8 units. However, according to the MRWC (2010) these data could be erroneous and could not be confirmed by the USEPA. Specific conductance ranged from 99 to 211 µS/cm.

The study also conducted continuous water quality monitoring over two weeks in 2009 off of the Lowell Motor Boat Club dock located on the right descending bank immediately upstream of the Pawtucket and Northern Canals in the Project's impoundment. Water temperature, dissolved oxygen, conductivity, and pH were recorded in 10-minute intervals from September 22 to October 5 at a depth of one meter. According to the

Project's Low Impact Hydropower Institute (LIHI) certification, results indicate that data met state quantitative water quality standards for parameters with numeric limits except episodic low pH readings (LIHI 2018).

NHDES Data

A search was conducted using the USEPA's STORET database for water quality data within the Project vicinity in Massachusetts and New Hampshire. Water temperature, DO, pH, and specific conductance data were available for the following three sites in New Hampshire, which were sampled by the NHDES (Figure E.7-9):

1. Bridge Connecting RTE 3 & 3A (Station ID 11113300-02-MER)
2. RTE 111 BRIDGE, EAST HOLLIS ST (Station ID 11113300-03-MER)
3. RR BRIDGE D.S. OF MANCHESTER WWTF (Station ID 11113300-08-MER)

Data collected over the past 20 years (1998-2015) are presented in Figure E.7-10 through Figure E.7-14. Water temperatures ranged up to 28°C. DO concentrations ranged from 6.6 to 10.8 mg/L, which were well above the minimum criterion in New Hampshire of 5.0 mg/L, and waters were 82.1 to 121.0 percent saturated. The pH ranged from 5.7 to 7.5 units and levels were frequently below the minimum criterion of 6.5 units. Specific conductance ranged from 64 to 180 µS/cm.

Merrimack River Watershed Assessment Study

DO concentrations were also monitored during the Merrimack River Watershed Assessment Study, which was a joint effort between federal, state, and local communities to develop a comprehensive watershed management plan for the Merrimack River (USACE 2018). During the study, water quality sampling was conducted along the mainstem of the Merrimack River from Concord, New Hampshire, to its estuary in Newburyport, Massachusetts. From 2003 to 2005, three dry-weather surveys and four wet-weather surveys were conducted. Additionally, a continuous survey of DO and temperature was conducted at two locations for a one-month period during low-flow conditions in August and September 2003. These data were not available, but the study summary indicated DO along the mainstem of the Merrimack River from Manchester, New Hampshire, to the Atlantic Ocean were well above the minimum criterion of 5 mg/L.

Figure E.7-9. USGS and STORET Water Quality Sample Locations and Proposed Project Boundary

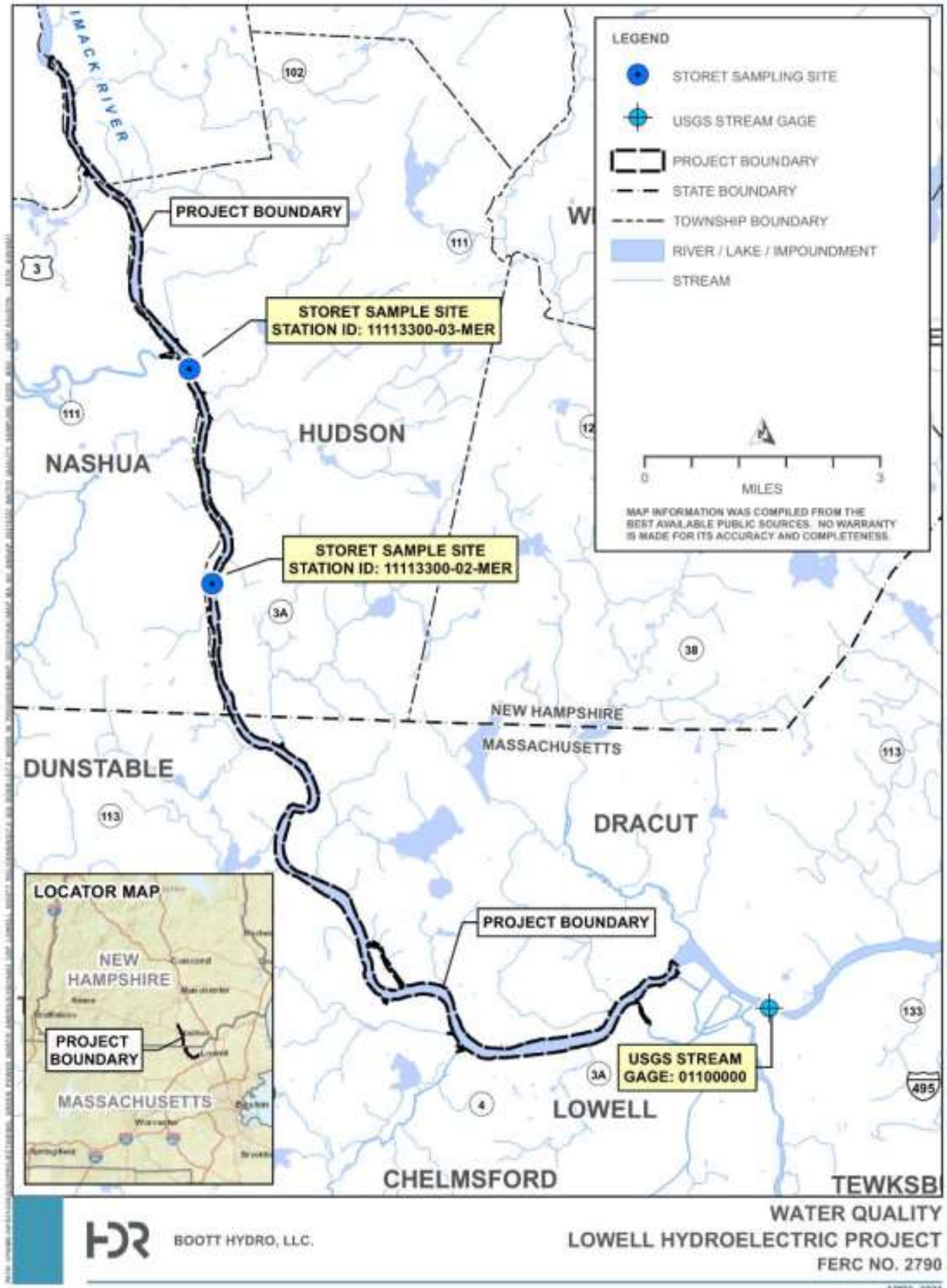


Table E.7-5. Summary of Water Quality Data Obtained in the Project's Impoundment and Bypassed Reach by NAI in 2019.

Location	Season	Water Temperature (°C)			Dissolved Oxygen (mg/L)			Conductivity (µS/cm)			pH (units)			Turbidity (NTU)		
		Average (Avg)	Minimum (Min)	Maximum (Max)	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
Impoundment	Spring	21.5	20.6	22.1	8.7	8.4	9.0	114.0	97.0	139.0	-	6.5	7.4	2.6	1.6	3.7
	Summer	25.6	25.2	26.0	8.4	8.1	8.8	181.0	166.0	199.0	-	6.7	7.5	1.8	1.5	1.9
	Fall	10.8	10.3	11.5	10.6	9.8	11.1	117.0	91.0	152.0	-	6.5	7.4	1.6	0.8	2.2
Bypassed Reach	Spring	-	22.9	22.9	-	9.5	9.5	-	148.0	148.0	-	6.5	6.5	-	-	-
	Summer	23.8	23.4	24.1	9.4	9.1	9.6	194.3	191.0	197.0	-	7.4	8.1	-	-	-
	Fall	13.1	13.0	13.2	9.8	8.9	10.6	100.3	95.0	104.0	-	6.3	6.8	-	-	-

Figure E.7-10. Water Temperature Data Collected at USGS Gage 01100000 *Merrimack River BL Concord River at Lowell, MA* on the Merrimack River, 1998 – 2004

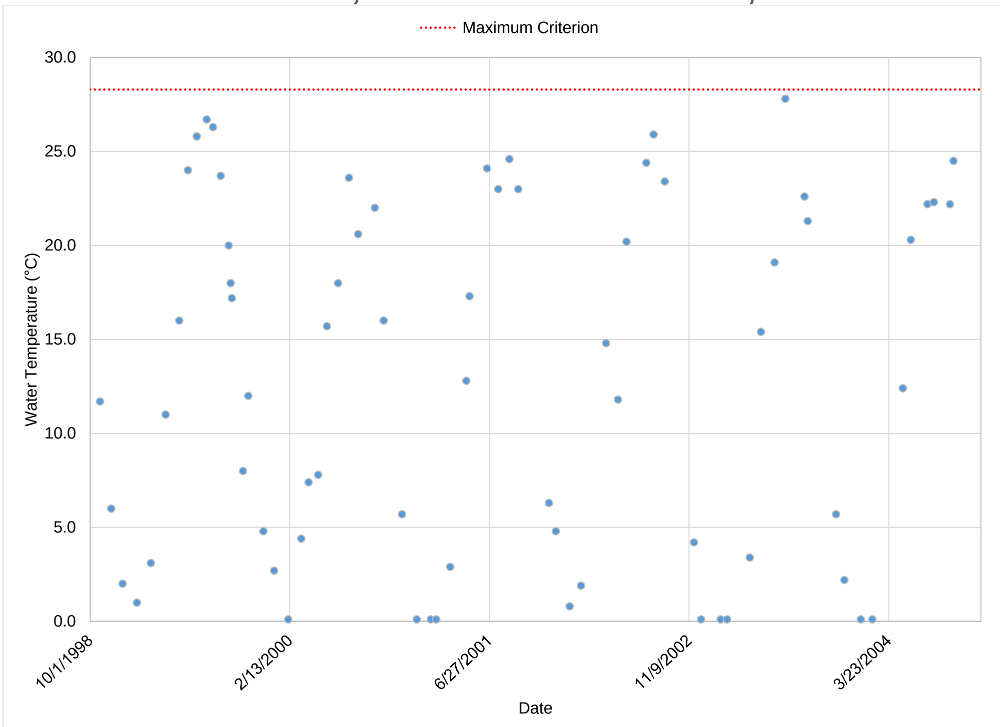


Figure E.7-11. Dissolved Oxygen Data Collected at USGS Gage 01100000 *Merrimack River BL Concord River at Lowell, MA* on the Merrimack River, 1998 – 2004

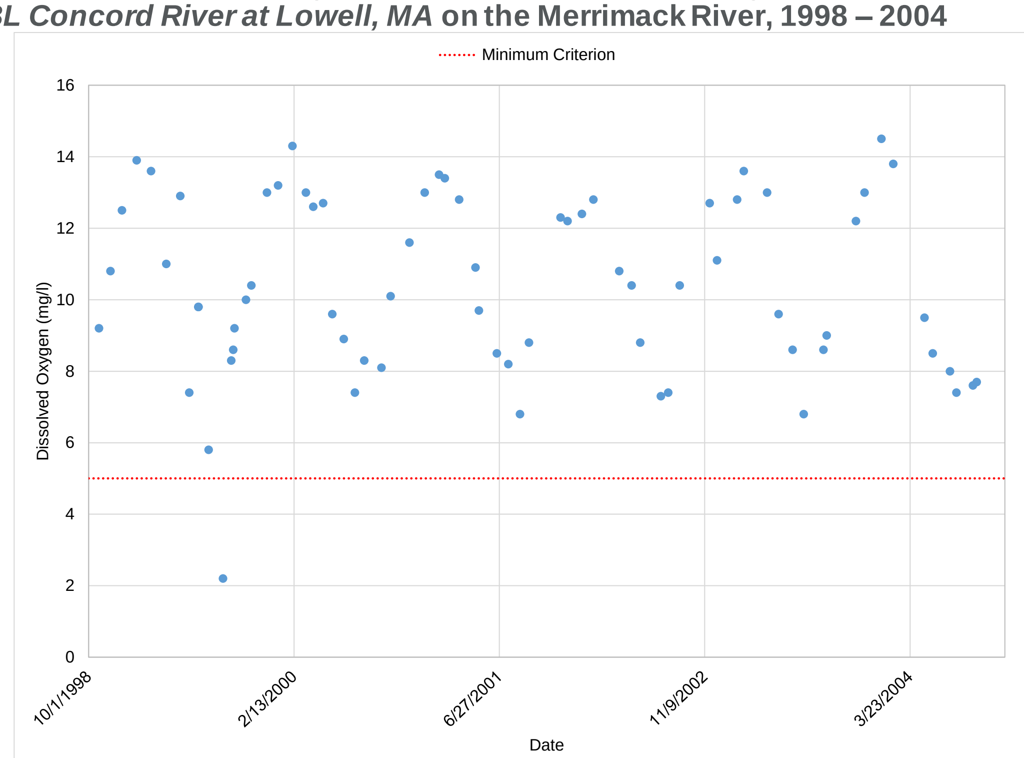


Figure E.7-12. Dissolved Oxygen Percent Saturation Data Collected at USGS Gage 01100000 *Merrimack River BL Concord River at Lowell, MA* on the Merrimack River, 1998 – 2004

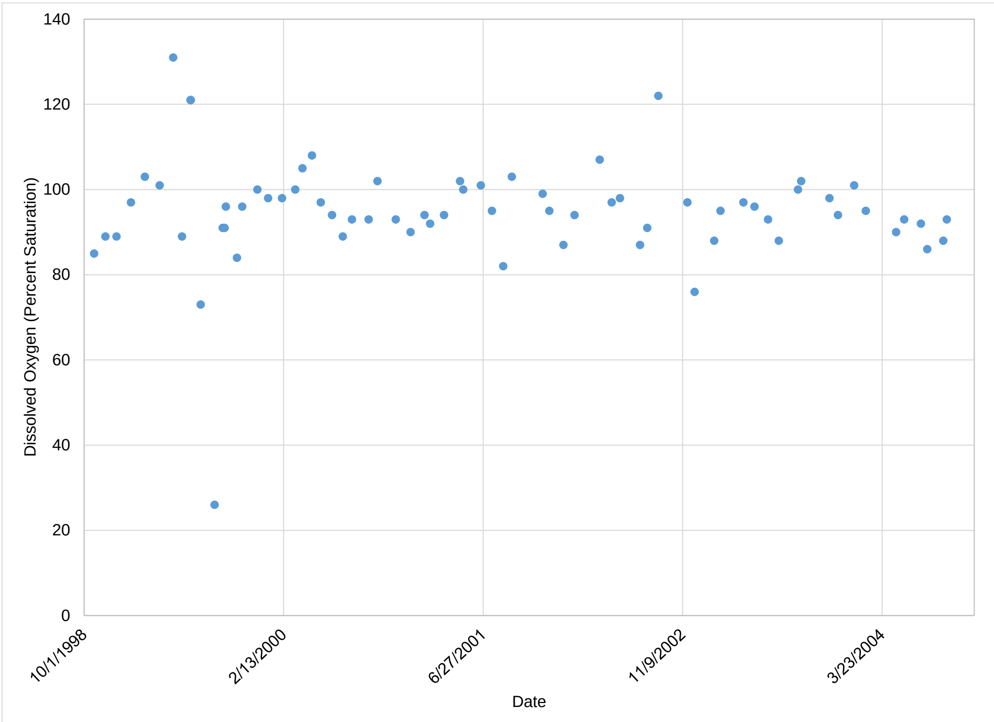


Figure E.7-13. pH Data Collected at USGS Gage 01100000 *Merrimack River BL Concord River at Lowell, MA* on the Merrimack River, 1998 – 2004

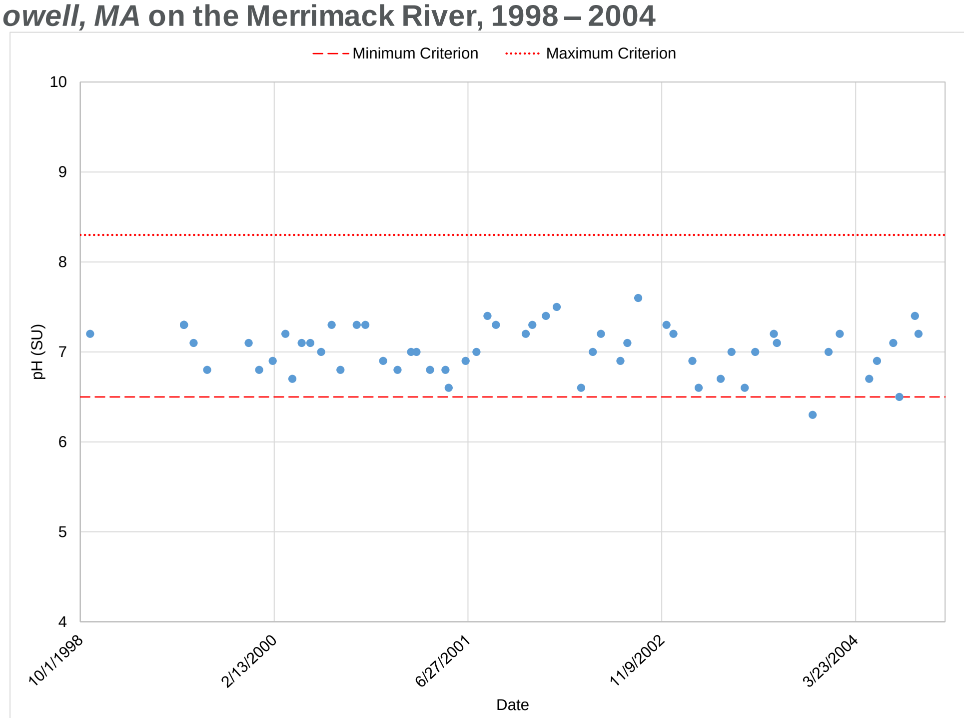


Figure E.7-14. Specific Conductance Data Collected at USGS Gage 01100000 *Merrimack River BL Concord River at Lowell, MA* on the Merrimack River, 1998 – 2004

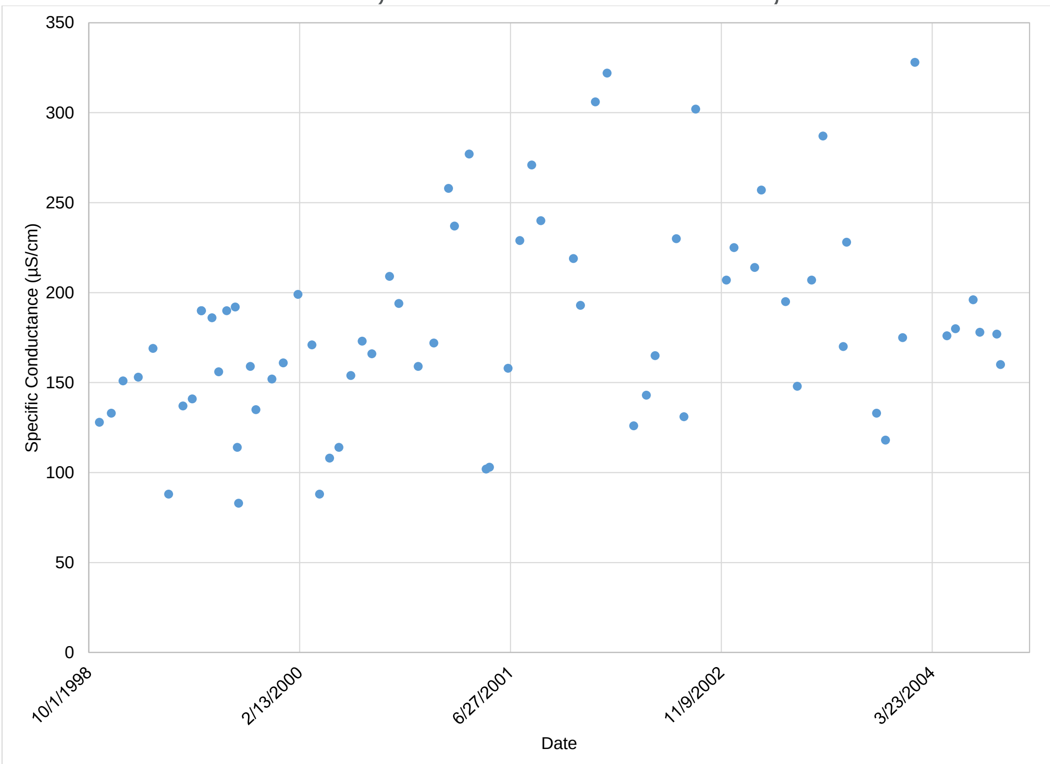


Table E.7-6. Water quality data collected by a volunteer monitoring program established by the MRWC at 9 sites along the Merrimack River from Essex Dam to the Pawtucket Dam in Lowell, 2009

River Mile	Description	Water Temperature (°C)						DO (mg/L)						pH (SU)						Specific Conductance (µS/cm)					
		14-May	30-May	11-Jun	23-Jul	1-Aug	13-Aug	14-May	30-May	11-Jun	23-Jul	1-Aug	13-Aug	14-May	30-May	11-Jun	23-Jul	1-Aug	13-Aug	14-May	30-May	11-Jun	23-Jul	1-Aug	13-Aug
29.6	Above Essex Dam	15.6	16.6	19.2	22.5	23.3	23.4	11.1	10.5	8.5	7.9	9.9	8.0	6.5	4.8	6.6	6.3	4.2	-	117	169	189	178	109	160
31.4	Methuen Water Intake	15.4	16.6	19.4	22.3	23.3	23.2	11.2	8.5	8.5	7.6	10.0	7.8	6.4	6.0	6.7	6.4	5.6	-	119	159	190	169	106	147
32.2	Bartlett Brook	15.4	16.5	19.3	22.4	23.3	23.1	11.6	8.2	8.5	7.6	10.0	7.8	6.4	6.1	6.6	6.4	4.6	-	118	157	194	169	103	144
33.4	Fish Brook	15.6	16.5	19.2	22.4	23.2	23.2	12.1	7.8	8.3	7.5	10.0	7.7	6.5	4.1	6.6	6.4	5.5	-	124	161	195	187	119	170
35.1	Gravel Pit	15.6	16.7	19.1	22.4	23.1	23	11.7	7.7	8.1	7.5	10.1	8.0	6.5	4.6	6.5	6.4	6.0	-	122	152	176	155	104	142
36.3	Trull Brook	15.4	16.9	19.2	22.5	23.0	23.2	11.6	7.8	8.7	7.9	10.2	7.9	6.4	4.3	6.7	6.4	6.0	-	111	170	211	177	99	166
37.9	Duck Island	15.4	16.8	19.2	22.4	-	23.1	11.7	7.6	8.6	7.7	-	7.9	6.2	5.8	6.6	6.3	-	6.5	106	135	176	151	-	133
38.9	Concord River	-	-	-	-	-	23.3	-	-	-	-	-	7.2	-	-	-	-	-	6.6	-	-	-	-	-	196
40.0	Oulette Bridge	-	-	-	-	-	23.2	-	-	-	-	-	7.7	-	-	-	-	-	6.5	-	-	-	-	-	122
	Minimum	15.4	16.5	19.1	22.3	23	23	11.1	7.6	8.1	7.5	9.9	7.2	6.2	4.1	6.5	6.3	4.2	6.5	106	135	176	151	99	122
	Maximum	15.6	16.9	19.4	22.5	23.3	23.4	12.1	10.5	8.7	7.9	10.2	8.0	6.5	6.1	6.7	6.4	6.0	6.6	124	170	211	187	119	196

Note: dash (-) indicates no data collected.

Table E.7-7. Water quality data collected by a volunteer monitoring program established by the MRWC at 8 sites along the Merrimack River from Pawtucket Dam to the Massachusetts/New Hampshire border, 2009

River Mile	Description	Water Temperature (°C)								DO (mg/L)								pH (SU)								Specific Conductance (µS/cm)							
		12-May	10-Jun	24-Jun	14-Jul	11-Aug	19-Aug	8-Sep	20-Oct	12-May	10-Jun	24-Jun	14-Jul	11-Aug	19-Aug	8-Sep	20-Oct	12-May	10-Jun	24-Jun	14-Jul	11-Aug	19-Aug	8-Sep	20-Oct	12-May	10-Jun	24-Jun	14-Jul	11-Aug	19-Aug	8-Sep	20-Oct
41.1	Pawtucket Dam	15.7	19.9	18.3	21.3	22.3	25.7	20.8	8.4	9.6	9.4	8.8	8.8	8.4	7.9	8.0	-	6.1	6.4	6.0	6.0	6.6	3.3	6.3	6.0	108	143	102	119	121	130	132	128
42.4	Rourke Bridge	15.6	19.8	-	21.4	22.3	-	20.5	8.1	9.4	8.4	-	8.8	8.4	-	8.0	-	6.2	6.4	-	6.1	6.7	-	6.3	5.9	104	145	-	118	120	-	132	121
43.4	Stony Brook	15.6	19.7	-	21.4	22.4	-	20.4	8.1	9.4	8.2	-	8.8	8.5	-	8.0	-	6.2	6.4	-	6.1	6.7	-	6.3	5.8	103	143	-	114	118	-	129	118
44.6	Vesper Country Club	15.5	19.7	-	21.4	22.4	-	20.2	8.2	9.3	8.0	-	8.8	8.3	-	8.0	-	6.2	6.5	-	6.2	6.6	-	6.3	5.9	103	141	-	114	119	-	127	120
46.4	Lawrence Brook	15.4	19.7	-	21.2	22.4	-	20.4	8.3	9.3	7.8	-	8.8	8.4	-	8.2	-	6.2	6.4	-	6.2	6.7	-	6.4	6.0	102	145	-	113	116	-	135	138
47.3	Tyngsborough (Rte. 113) bridge	15.3	19.6	-	21.2	22.4	-	20.5	8.3	9.3	7.8	-	8.8	8.3	-	8.2	11.9	6.2	6.4	-	6.2	6.7	-	6.4	5.9	100	144	-	113	116	-	133	131
48.9	Limit Brook	15.3	19.3	-	21.1	22.5	-	20.5	8.3	9.3	7.7	-	8.7	8.5	-	8.3	11.6	6.2	6.4	-	6.1	6.7	-	6.3	5.9	102	144	-	112	111	-	128	123
49.6	MA/NH border	15.3	19.2	18.2	21.1	22.4	-	20.4	8.3	9.4	7.7	9.8	8.8	8.3	-	8.0	11.6	6.3	6.4	6.0	6.0	6.8	-	6.3	5.9	99	142	99	114	114	-	129	129
	Minimum	15.3	19.2	18.2	21.1	22.3	25.7	20.2	8.1	9.3	7.7	8.8	8.7	8.3	7.9	8.0	11.6	6.1	6.4	6.0	6.0	6.6	3.3	6.3	5.8	99	141	99	112	111	130	127	118
	Maximum	15.7	19.9	18.3	21.4	22.5	25.7	20.8	8.4	9.6	9.4	9.8	8.8	8.5	7.9	8.3	11.9	6.3	6.5	6.0	6.2	6.8	3.3	6.4	6.0	108	145	102	119	121	130	135	138

Note: dash (-) indicates no data collected.

Table E.7-8. Water quality data collected by a volunteer monitoring program established by the MRWC at 7 sites along the Merrimack River from Massachusetts/New Hampshire border to Greeley Park in Nashua, 2009

River Mile	Description	Water temperature (°C)					DO (mg/L)					pH (SU)					Specific conductance (µS/cm)				
		12-May	13-Jul	11-Aug	8-Sep	20-Oct	12-May	13-Jul	11-Aug	8-Sep	20-Oct	12-May	13-Jul	11-Aug	8-Sep	20-Oct	12-May	13-Jul	11-Aug	8-Sep	20-Oct
49.9	Pheasant Lane Mall	-	21.0	22.4	20.3	8.3	-	8.3	8.4	8.0	11.3	-	6.3	6.7	6.4	5.9	-	117	121	132	127
50.9	Spit Brook	15.5	21.1	22.4	20.3	8.3	9.3	8.4	8.3	8.2	11.3	6.3	6.3	6.8	6.4	5.9	103	128	116	133	126
51.8	Unnamed stream	-	20.9	-	-	-	-	8.7	-	-	-	-	6.0	-	-	-	-	97	-	-	-
52.5	Nashua Country Club	-	20.9	-	-	-	-	8.6	-	-	-	-	6.3	-	-	-	-	139	-	-	-
53.1	Nashua WWTP	-	20.9	-	-	-	-	8.6	-	-	-	-	6.5	-	-	-	-	199	-	-	-
54.4	Nashua River	-	20.8	-	-	-	-	8.6	-	-	-	-	6.2	-	-	-	-	164	-	-	-
55.9	Greeley Park	-	21.2	-	-	-	-	8.9	-	-	-	-	6.2	-	-	-	-	96	-	-	-
	Minimum	15.5	20.8	22.4	20.3	8.3	9.3	8.3	8.3	8.0	11.3	6.3	6.0	6.7	6.4	5.9	103	96	116	132	126
	Maximum	15.5	21.2	22.4	20.3	8.3	9.3	8.9	8.4	8.2	11.3	6.3	6.5	6.8	6.4	5.9	103	199	121	133	127

Note: dash (-) indicates no data collected.

Figure E.7-15. Water Temperature STORET Data Collected at three sites by the NHDES in the Merrimack River, 1998 – 2015

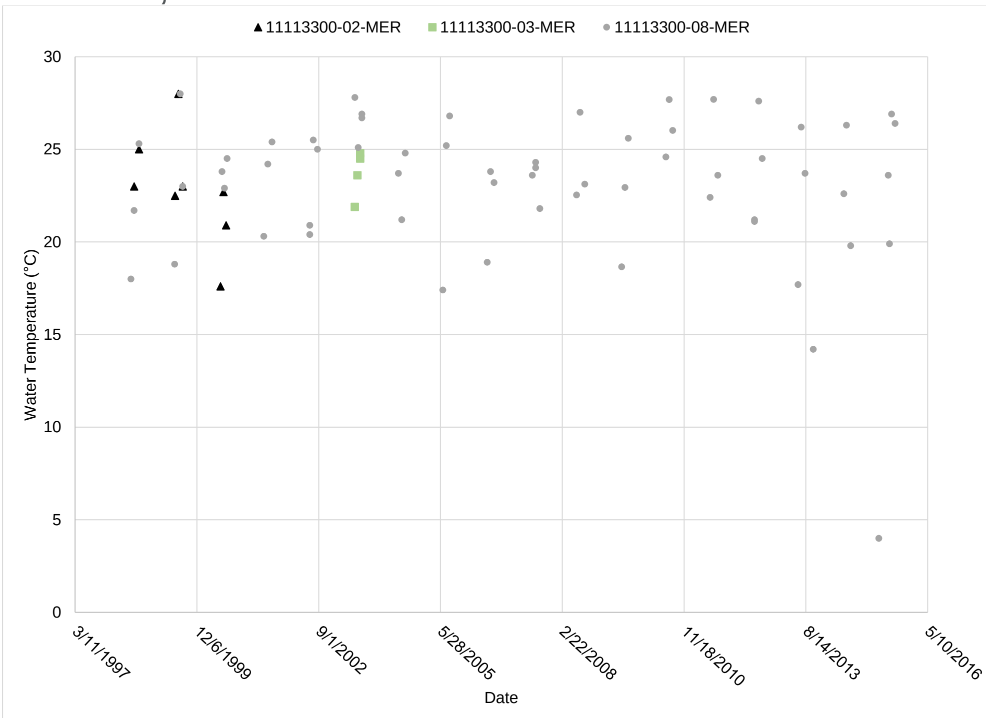


Figure E.7-16. Dissolved Oxygen STORET Data Collected at three sites by the NHDES in the Merrimack River, 1998 – 2015

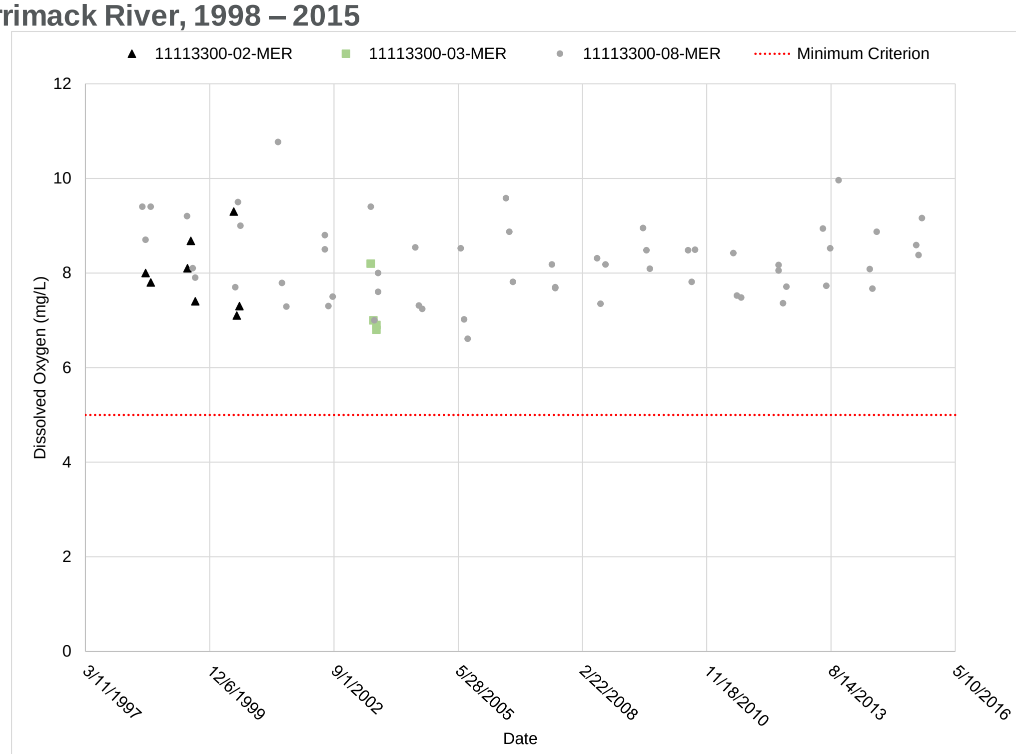


Figure E.7-17. Dissolved Oxygen Percent Saturation STORET Data Collected at three sites by the NHDES in the Merrimack River, 1998 – 2015

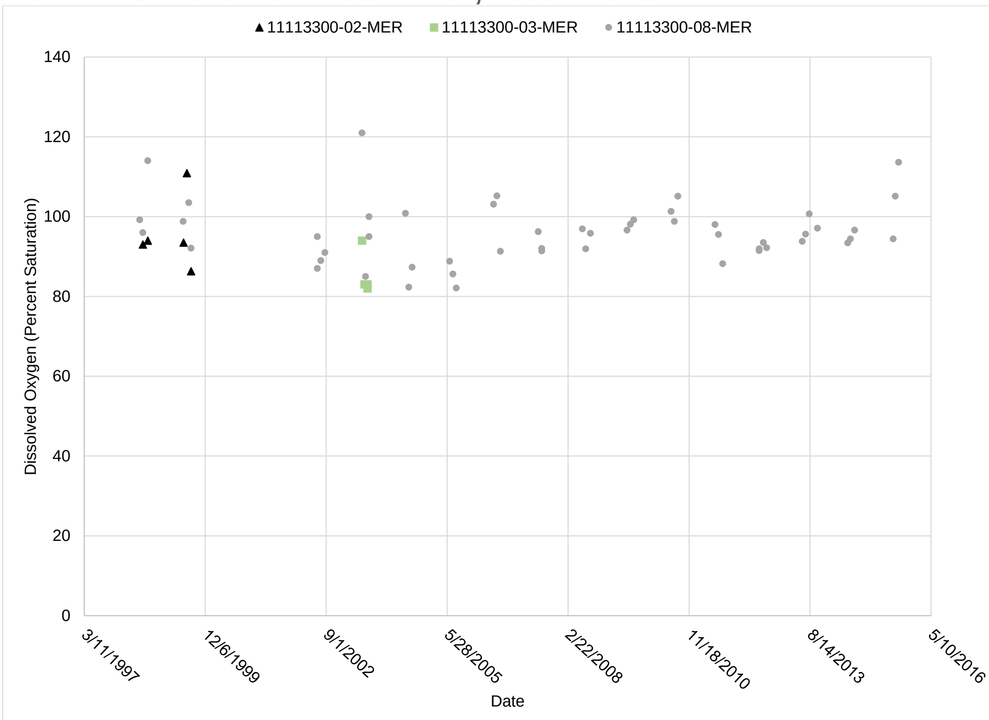


Figure E.7-18. pH STORET Data Collected at three sites by the NHDES in the Merrimack River, 1998 – 2015

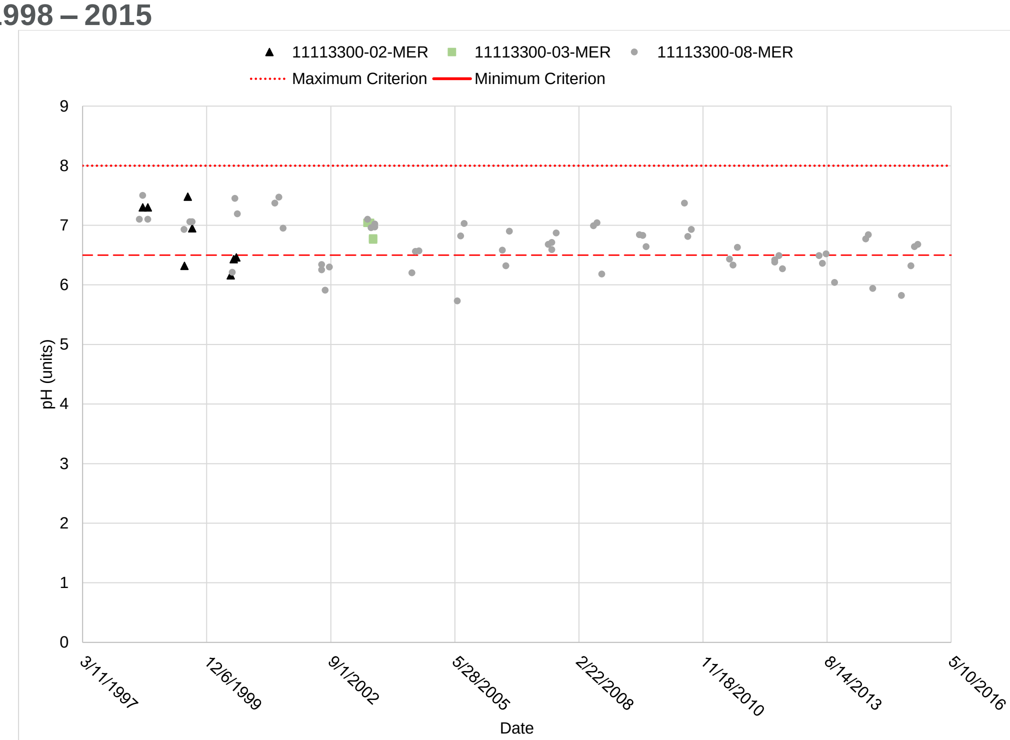
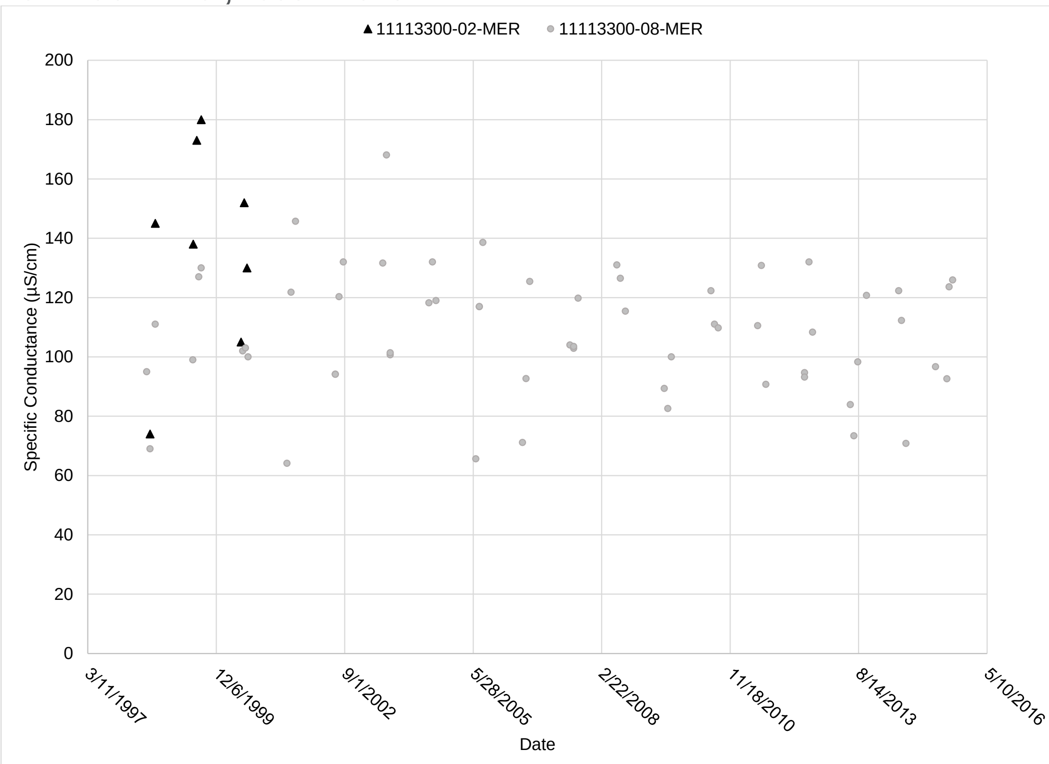


Figure E.7-19. Specific Conductance STORET Data Collected at two sites by the NHDES in the Merrimack River, 1998 – 2015



E.7.2.1.5 Use Impairment

An Integrated List of Waters (Integrated List) for Massachusetts and New Hampshire is submitted to the USEPA in fulfillment of reporting requirements under the Clean Water Act (CWA). Section 303(d) of the CWA requires states to identify those water bodies that are not expected to meet surface water quality standards after the implementation of technology-based controls and to prioritize and schedule them for the derivation of total maximum daily loads (TMDLs).

E.7.2.1.6 Massachusetts

The Integrated List in Massachusetts assigns waterbody segments to one of five categories, depending upon their status with respect to designated use support (Table E.7-9). The Merrimack River is listed as Category 5 impaired waters in Massachusetts, which includes portions within the Project vicinity (Table E.7-10) (MADEP 2016). Probable sources contributing to impairment included atmospheric deposition, CSOs from municipal discharges, impacts from hydrological flow regulation/modification, wet weather discharges from municipal discharges/sewage, municipal point source discharges of municipal discharges/sewage, and urban-related runoff/stormwater. The canal system at the Project is also listed as Category 5 waters (MADEP 2016).

A draft Pathogen TMDL has been drafted for the Merrimack River Watershed (MADEP et al. undated). No other TMDLs were located for the Merrimack River Watershed (Commonwealth of Massachusetts 2020b).

Table E.7-9. Description of Integrated Report Categories in Massachusetts (MADEP 2016)

Category	Description
1	Unimpaired and not threatened for all designated uses
2	Unimpaired for some uses and not assessed for others
3	Insufficient information to make assessments for any uses
4	Impaired or threatened for one or more uses, but not requiring the calculation of a TMDL
5	Impaired or threatened for one or more uses requiring a TMDL

Table E.7-10. Impaired Water Segments within the Lowell Project vicinity (MADEP 2016)

Name	Segment ID	Description	Length (miles)	Impairment
Project Impoundment	MA84A-01	State line at Hudson, NH/Tyngsborough, MA to Pawtucket Dam, Lowell	9	*Escherichia Coli* (*E. Coli*) Fecal coliform Mercury in fish tissue
Project Canal System	MA84A-29	Canal System near Pawtucket Falls, Lowell	4.90	DDT in fish tissue Lead Mercury in fish tissue PCBs in fish tissue
Bypassed/ Downstream Reach	MA84A-02	Pawtucket Dam, Lowell to Lowell Regional Wastewater Utilities outfall at Duck Island, Lowell	3.2	Dewatering* *E. Coli* Mercury in fish tissue Total phosphorus
Downstream Reach	MA84A-03	Lowell Regional Wastewater Utilities outfall at Duck Island, Lowell to Essex Dam, Lawrence	8.80	*E. Coli* Mercury in fish tissue PCBs in fish tissue
Reach Downstream of Essex Dam	MA84A-04	Essex Dam, Lawrence to confluence with Little River, Haverhill	10.00	*E.Coli* PCBs in fish tissue Total phosphorus

*TMDL not required (non-pollutant).

E.7.2.1.7 New Hampshire

The Section 305(b) and 303(d) consolidated list in New Hampshire assigns waterbody segments to various categories (Table E.7-11). Portions of the Merrimack River in New Hampshire are identified as Category 5 waters and are included in the 2018 303(d) list (Table E.7-12) (NHDES 2019b). Sources of impairment in these sections are unknown.

Table E.7-11. Description of Integrated Report Categories in New Hampshire

Category	Description
1	Attaining all designated uses and no use is threatened.
2	Attaining some of the designated uses; no use is threatened; and insufficient or no data and information is available to determine if the remaining uses are attained or threated (i.e., more data is needed to assess some of the uses).
3	Insufficient or no data and information are available to determine if any designated use is attained, impaired, or threatened (i.e., more monitoring is needed to assess any use).
4	Impaired or threatened for one or more designated uses but does not require development of a TMDL because:
4A	A TMDL has been completed, or
4B	Other pollution control requirements are reasonably expected to result in attainment of the water quality standard in the near future, or
4C	The impairment is not caused by a pollutant.
5	Impaired or threatened for one or more designated uses by a pollutant(s), and requires a TMDL, which is the 303(d) list.

Table E.7-12. Impaired Water Segments within Project vicinity in New Hampshire (NHDES 2019b)

Assessment Unit ID	Water Name	Primary Town	Water Size (miles)	Use Description	Impairment Name	DES Category	TMDL Priority
NHRIV700061206-24	Merrimack River	Nashua	5.2	Aquatic Life	Aluminum	5-M	Low
					pH	5-M	Low
				Primary Contact Recreation	Chlorophyll-a	5-M	Low
NHRIV700061002-14	Merrimack River	Nashua	3.7	Aquatic Life	pH	5-M	Low
				Primary Contact Recreation	Creosote	5-M	Low

E.7.2.2 Environmental Analysis

FERC's SD2 identified effects of continued Project operations on streamflow and water quality in the impoundment, canal system, bypassed reach, and Merrimack River.

- Effects of continued project operation on flooding along the shoreline of the project impoundment and surrounding areas.
- Effects of continued project operation on streamflow in the impoundment, canal system, bypassed reach, and Merrimack River.
- Effects of continued project operation on water quality in the impoundment, canal system, bypassed reach, and Merrimack River.

The Project operates in a ROR mode and has no useable storage capacity. Therefore, seasonal and annual variations in flows within the Project area are based on natural hydrologic conditions in the Merrimack River Watershed. In 2011, the MADEP specified that it had waived Water Quality Certification related to a Project license amendment (i.e., replacement of the flashboard system with the crest gate system) (LIHI 2018), which suggests there were not water quality concerns at that time and there have been no substantial changes to Project operations since.

In 2019, the licensee completed the construction of a pneumatically operated crest gate on the spillway crest to maintain the headpond at its normal level of 92.2 feet NGVD 1929. The system was installed to prevent flooding in the impoundment zone, after backwater analysis and technical evaluation found the system would enhance project operational control and generation, and would provide significant advantages for other resources that are dependent on water levels, including flood control, recreation, and fish passage. The Commission's Environmental Assessment completed prior to the crest gate installation noted up to 46 miles of shoreline aquatic habitat could benefit from installing the crest gate, and the system would normally provide slightly lower water level elevations during flood events of less than 75,000 cfs. The Pawtucket Dam spillway becomes submerged at flows greater than 75,000 cfs, which causes the water level upstream to be influenced by the river channel structure within the bypassed reach downstream of the dam. The proposal was strongly endorsed by the Massachusetts Division of Fish and Wildlife (MADFW) and NMFS, who both noted the project's beneficial effect on fish habitat and movement within the project area (FERC 2011).

Some hydroelectric facilities can influence instream flows, and those that have large deep impoundments impact to water quality. The Project is operated as a ROR hydroelectric project. Therefore, the Project's ability to influence flow and thus water quality is minimal due to its limited storage and hydraulic capacity. At the normal pond elevation of 92.2 feet NGVD 29 (crest of the pneumatic flashboards), the surface area of the impoundment encompasses an area of approximately 1,236 acres. The gross storage capacity between the normal surface elevation of 92.2 feet and the minimum pond level of 87.2 feet (at spillway crest) is approximately 6,180 acre-feet.

Under current operations, when river flows exceed the hydraulic capacity of the E.L. Field Powerhouse units (3,300 cfs per unit or 6,600 cfs for both units), excess flows up to approximately 2,000 cfs are routed through the downtown canal system and to the canal units. Any flows in excess of approximately 8,600 cfs (6,600 cfs at E.L. Field plus 2,000 cfs via canals) are passed over the Pawtucket Dam spillway. Pursuant to Article 37, operating the Project in ROR mode meets and exceeds the present Project minimum flow requirement of 1,990 cfs or inflow, whichever is less, as measured immediately downstream from the Project (Boott 2017). As a result of the Project's ROR operations, there is a constant flow downstream of the Project during summer low flow conditions, which prevents impacts to downstream water quality.

In support of relicensing the Project, water quality data were collected in the Project's impoundment and bypass reach during the Fish Assemblage Study in the spring, summer, and fall of 2019. Water temperature, dissolved oxygen, conductivity, and pH data were collected at 12 locations throughout the impoundment and at three locations throughout the bypass reach. Turbidity data was also collected at the impoundment site locations. All data collected in the impoundment and bypassed reach met state water quality standards. Additionally, as stated above, waters in the Project impoundment, bypassed reach, and downstream reaches have historically met state water quality standards. This suggests that the Project operation has little to no effect on the overall water quality in the Merrimack River, which is consistent with a ROR hydroelectric project. Water quality data indicates that water quality in the Project area is consistent with the water quality of the lower Merrimack River and is likely driven by natural environmental and biological factors as well as anthropogenic disturbance within the larger context of this regional portion of the river basin. Since the Project operates in a ROR mode, seasonal and annual variations in flows within the Project area are based on natural hydrologic conditions in the Merrimack River Watershed. Continued operation of the Project is not expected to have negative effects on water quality, and therefore the fish and aquatic resources in the Merrimack River.

Water quality data have been collected throughout the general Project area including throughout the 16-mile impoundment, the bypassed reach, and downstream from the Project in the Merrimack River. Much of these data were collected during the summer months and data were collected in the bypassed reach during minimum flows. Often these are when water temperatures are highest and dissolved oxygen levels are lowest. Regardless, water quality met state standards.

The man-made canal system utilizes flows upstream of the Pawtucket dam and discharges at multiple locations just upstream of the USGS gage 1.6 RM downstream of the Project. The data obtained from this gage met state water quality standards and there is no indication that the canal system is impacting water quality in the Merrimack River. The waters of the canal system are listed as impaired by the state of Massachusetts; however, the impairments (i.e., Dichlorodiphenyltrichloroethane [DDT] in fish tissue, lead, and mercury/PCBs in fish tissue) are not related to the Project or Project operations and are likely a result of atmospheric deposition and historical contamination from the mills and industrial facilities that line the canal system (LIHI 2018).

As stated elsewhere in this application for license, Boott proposes to remove the four mill power stations and associated canal infrastructure from the new FERC license. Boott will continue to manage the its canal structures and facilities, water levels and flows in line with current agreements with the NPS and other stakeholders.

E.7.2.3 Proposed Environmental Measures

Boott proposes continued operation of the Project with certain PM&E measures consistent with the measures required by the Project's existing license. Boott believes that the continued operation of the Project, as proposed, will limit effects on water quality and quantity. Boott proposes to operate the Project in a ROR mode using automatic pond level control of the E.L. Field powerhouse units. ROR operation may be temporarily modified for short periods to allow flow management for other project and non-project needs, e.g., downtown canal water level management, raising the crest gates following a high-water event, or for recreational purposes.

Boott also proposes to release a minimum flow of 100 cfs or inflow, whichever is less, to the bypass reach downstream of the Pawtucket Dam during the period outside of the fish passage season. During the fish passage season, which generally runs from late April through mid-July, the Licensee proposes to release a minimum flow of 500 cfs into the bypass reach via the existing fish ladder at the Pawtucket Dam. The operating period for the fish ladder will continue to be determined annually through consultation with the MRTC, consistent with current practice.

Boott proposes to continue to adhere to the Crest Gate Operation Plan approved by FERC on March 30, 2015, and operate fish passage facilities as determined in consultation with the MRTC.

E.7.2.4 Unavoidable Adverse Impacts

Continued Project operations as proposed by the Licensee are not expected to have any unavoidable adverse impacts on water quality or quantity. However, Boott notes that certain studies required by the Commission are ongoing, including the Three-Dimensional CFD Modeling Study. Boott will consult with stakeholders regarding the results and recommendations of this study and potential PM&E measures. As appropriate, Boott may propose additional PM&E measures in a supplement to this license application.

E.7.3 Fish and Aquatic Resources

The subsections below describe fish and aquatic resources in the vicinity of the Project and consider the effects of continued operation of the Project as proposed by the Licensee on these resources. Descriptions of the affected environment, the environmental analysis, the proposed environmental measures, and the identification of unavoidable adverse effects were developed based on available data presented in the Licensee's PAD, and the:

- Downstream American Eel Passage Assessment Study Report (NAI 2021a)
- Juvenile Alosine Downstream Passage Assessment Study Report (NAI 2021b)
- Upstream and Downstream Adult Alosine Passage Assessment Study Report (NAI 2021c)
- Fish Assemblage Study Report (NAI 2021d)
- Instream Flow Habitat Assessment and Zone of Passage Study (NAI 2021e)
- Fish Passage Survival Study (NAI 2021f)

These reports are included in Appendix B of this exhibit. However, Boott notes that certain studies required by the Commission are ongoing, including the Three-Dimensional CFD Modeling Study. Boott will consult with stakeholders regarding the results and recommendations of this study and potential PM&E measures. As appropriate, Boott may propose additional PM&E measures in a supplement to this license application.

E.7.3.1 Affected Environment

E.7.3.1.1 Overview

Historically, the Merrimack River served as a major resource for fisheries. However, the increase in industrial and urban pollution and construction of numerous dams along its length during the past two hundred years resulted in lowering the value of the river as an important aquatic habitat. The most affected fish populations have been the sensitive migrating species: anadromous fish that live in salt water and spawn in fresh water, and catadromous species that inhabit the river and spawn in the ocean. The changes in water quality of the Merrimack River combined with impoundments created by dams has increased the warm water fisheries habitat and resulted in the demise or severe reductions of migratory fish species (Massachusetts Department of Transportation Federal Highway Administration [FHA] and The Commonwealth of Massachusetts Department of Public Works [MDPW] 1985).

In more recent years, the quality of the Merrimack River has improved, and today there is a concerted effort on the part of state and federal fish and wildlife agencies to restore anadromous fish populations in the Merrimack River. These restoration efforts have included stocking the headwaters of the river with adult American shad (*Alosa sapidissima*) and juvenile Atlantic salmon (*Salmo salar*) and building fish ladders at dams to allow fish access to the upper reaches of the Merrimack River. Other anadromous fish that are returning to the Merrimack River include the alewife (*Alosa pseudoharengus*), blueback herring (*Alosa aestivalis*), and sea lamprey (*Petromyzon marinus*). According to the FHA and MDPW (1985), the only catadromous species in the Lowell portion of the Merrimack River is the American eel (*Anguilla rostrata*).

In 1969 the State of New Hampshire, the Commonwealth of Massachusetts, USFWS, United States Forest Service (USFS), and the NMFS combined their efforts and formed Policy and Technical Committees for the Anadromous Fishery Management of the Merrimack River. Largely through the efforts of these committees, much progress has recently been made (Boott Mills 1980).

The MRTC was formed to address the restoration of anadromous fish in the Merrimack River watershed and includes representatives from the following government organizations: New Hampshire Department of Fish and Game (NHDFG), MADFW, Massachusetts Division of Marine Fisheries (MADMF), USFWS, USFS, and NMFS (Technical Committee 2010). The MRTC coordinates restoration activities such as installation, evaluation, operation, and maintenance of fish passage and capture facilities at hydroelectric facilities along the Merrimack River. Boott collaborates with the MRTC under an adaptive management framework regarding all activities related to managing the fishery resources impacted by the Lowell Project.

The MRTC oversees the management of the Lowell Project fisheries as directed by the Project's CFPP which was filed pursuant to articles 35 and 36 of the Project's existing license and approved by FERC in November 2000. The CFPP and fish passage at the Project is described in more detail in Section E.7.3.1.4.

E.7.3.1.2 Aquatic Habitat

Aquatic habitat found in the Project vicinity consists of habitat types typical of most northeastern large rivers, which support a variety of cool and warm water species. Shallow water, littoral, and riparian habitat types exist along the shoreline of the Project's impoundment, as well as along the several islands scattered in the Project's impoundment. At low river flows, the habitat in the Project's bypass reach is generally broad, relatively shallow, and rocky with numerous areas of exposed bedrock, with a large pool occupying the middle portion of the bypass reach.

During the 2019 Fish Assemblage Study (NAI 2021d), habitat was visually evaluated and characterized in the impoundment and bypass reach. The dominant substrate, proportion of transect with submerged aquatic vegetation, and the proportion of transect with overhanging vegetative cover was recorded. Water depth and velocity was measured within each sampling transect. Water quality data (i.e., water temperature, dissolved oxygen, conductivity, pH, and turbidity data) was also collected during spring, summer, and fall at each transect at a depth of one meter.

Impoundment

Within the impoundment, habitat was identified primarily as impoundment (78%), with less amounts of run (7%) and pool (15%) habitat. Dominant substrate, presence of submerged aquatic vegetation (SAV), and presence of general cover were consistent among all sample units regardless of mesohabitat classification (i.e., pool, run or impoundment). Sampled areas upstream of Pawtucket Dam were characterized by sand-silt-clay sediments, presence of SAV over 0-25% of the sample area and the presence of general cover over 0-25% of the sample area. Mean water depth (as sampled at quarter points of the river channel at the upper, middle, and lower points of each transect) trended towards shallower at the upper end of the reach upstream of Pawtucket Dam in areas classified as pool and run, and deeper at the lower end in areas classified as impoundment (NAI 2021d).

Water temperature in the impoundment was relatively consistent among sample units with a ± 1-2°C range in values within each season. The average Merrimack River water temperature was 21.5°C during the spring sampling, 25.6°C during the summer sampling, and 10.8°C during the fall sampling. Dissolved oxygen was measured at 8.1 mg/L or greater at all stations upstream of Pawtucket Dam regardless of season. Conductivity averaged 114 µs/cm during the spring sampling, 181 µs/cm during the summer sampling, and 117 µs/cm during the fall sampling. In general, conductivity increased with proximity to the Pawtucket Dam. River pH was consistent across seasons ranging from 6.5-7.5. The average turbidity reading was higher during the spring sampling (2.6 Nephelometric Turbidity Units [NTUs]) than was observed during the summer or fall periods (1.8 and 1.6 NTUs, respectively) (NAI 2021d).

Bypass Reach

Within the bypass reach, habitat was identified primarily as pooled sections (75%) with ledge channels (25%). A range of substrate types was sampled during each of the three seasons, ranging from areas of boulders to sand-silt-clay habitat. Sampled areas within the bypass reach were characterized by the presence of SAV over 0-25% of the sample area and the presence of general cover over 0-25% of the sample area. Mean water depth was consistent among sample areas and season, ranging from 1.5-2.4 feet (NAI 2021d).

Water temperature was relatively consistent among sample units within each season and averaged 22.9°C during the spring sampling, 23.8°C during the summer sampling, and 13.1°C during the fall sampling. Dissolved oxygen was measured at 8.9 mg/L or greater at all bypass reach stations downstream of Pawtucket Dam regardless of season. Conductivity averaged 148 µs/cm during the spring sampling, 194 µs/cm during the summer sampling, and 100 µs/cm during the fall sampling. The average river pH in the bypass reach was higher during the summer sampling event (7.8) than was observed during the spring (6.5) or fall (6.6) (NAI 2021d).

During the Instream Flow Habitat Assessment and Zone of Passage Study (NAI 2021e), an aquatic habitat model was developed for 9 species and associated life stages in the Bypass Reach through the bedrock rapids to the tailrace confluence at flows from 250 cfs to 14,000 cfs. An index of suitable habitat at each modeled flow, expressed as weighted usable area (WUA) in m^2, is presented below in Table E.7-13. Figure E.7-20 illustrates the flow:habitat relationships for each species and life stage.

Table E.7-13. Weighted Usable Area (WUA) in m2 in the Bypass Reach according to flow, species, and life stage

Flow	American Shad	River Herring	Sea Lamprey	Fallfish

cfs	Juvenile	Spawning	Spawning	Spawning	Juvenile	Adult
250	11,923	6,738	3,110	576	2,764	15,133
482	14,468	9,368	2,951	1,012	3,134	17,586
1,000	15,864	12,859	2,421	1,599	2,873	18,363
2,000	14,946	15,664	1,711	1,908	1,726	14,308
4,345	9,948	15,755	1,011	1,282	893	8,219
6,000	7,558	13,396	820	858	895	6,782
7,011	6,517	11,852	723	724	894	6,201
8,000	5,710	10,313	675	611	819	5,724
10,000	4,644	7,864	568	489	688	4,979
12,000	4,025	6,418	523	415	511	4,573
14,000	3,641	5,718	490	355	371	4,277
Flow	**Smallmouth Bass**				**Longnose Dace**	
cfs	**Fry**	**Juvenile**	**Adult**	**Spawning**	**Juvenile**	**Adult**
250	10,617	10,141	5,834	879	838	1,970
482	10,491	12,772	7,155	727	1,086	2,414
1,000	7,768	13,820	8,021	508	735	1,657
2,000	5,507	11,407	6,350	324	385	848
4,345	3,340	6,793	4,014	215	283	537
6,000	2,817	5,412	3,366	201	296	580
7,011	2,454	4,882	3,087	173	265	599
8,000	2,270	4,394	2,818	161	212	508
10,000	1,899	3,665	2,402	143	116	303
12,000	1,660	3,249	2,153	104	69	160
14,000	1,526	2,983	2,016	98	44	109
Flow	**White Sucker**			**Freshwater Mussels**	**Benthic Macro-invertebrates**	
cfs	**Fry**	**Juvenile**	**Adult**	**Rearing**	**Rearing**	
250	25,085	10,724	159	8,217	7,213	
482	22,449	12,398	95	9,686	12,031	
1,000	16,881	10,462	61	10,937	18,958	
2,000	11,986	6,989	21	11,066	24,062	
4,345	7,219	4,352	69	8,528	21,698	

6,000	6,041	3,758	123	6,679	17,847	
7,011	5,233	3,361	95	5,802	15,777	
8,000	4,787	3,165	66	5,039	13,819	
10,000	4,065	2,706	34	3,913	10,948	
12,000	3,657	2,481	12	3,244	8,867	
14,000	3,488	2,354	9	2,866	7,250	

Figure E.7-20. Relationship between WUA (m²) and flow (cfs) in Bypass Reach according to species and life stage

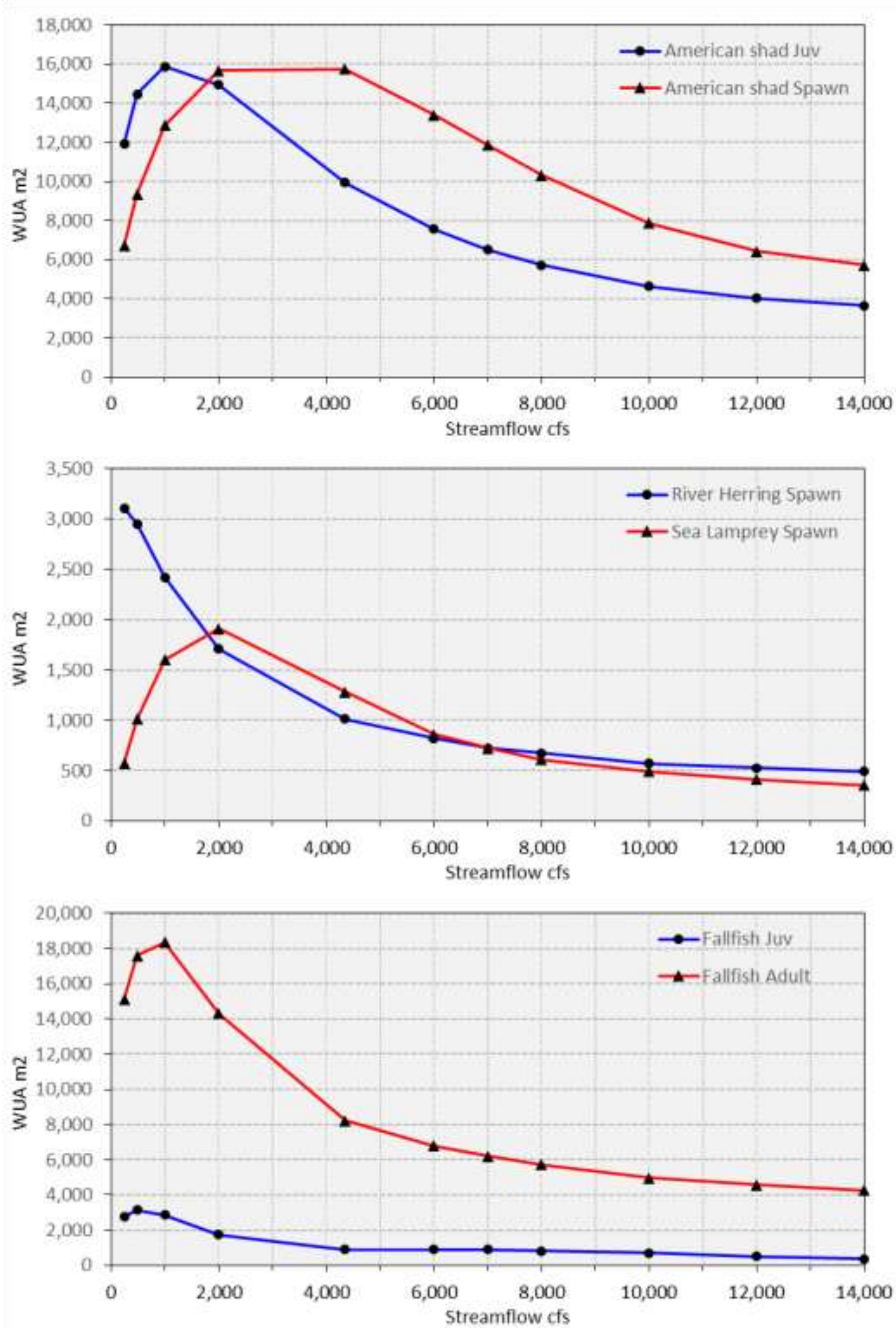


Figure E.7-20 (Continued)

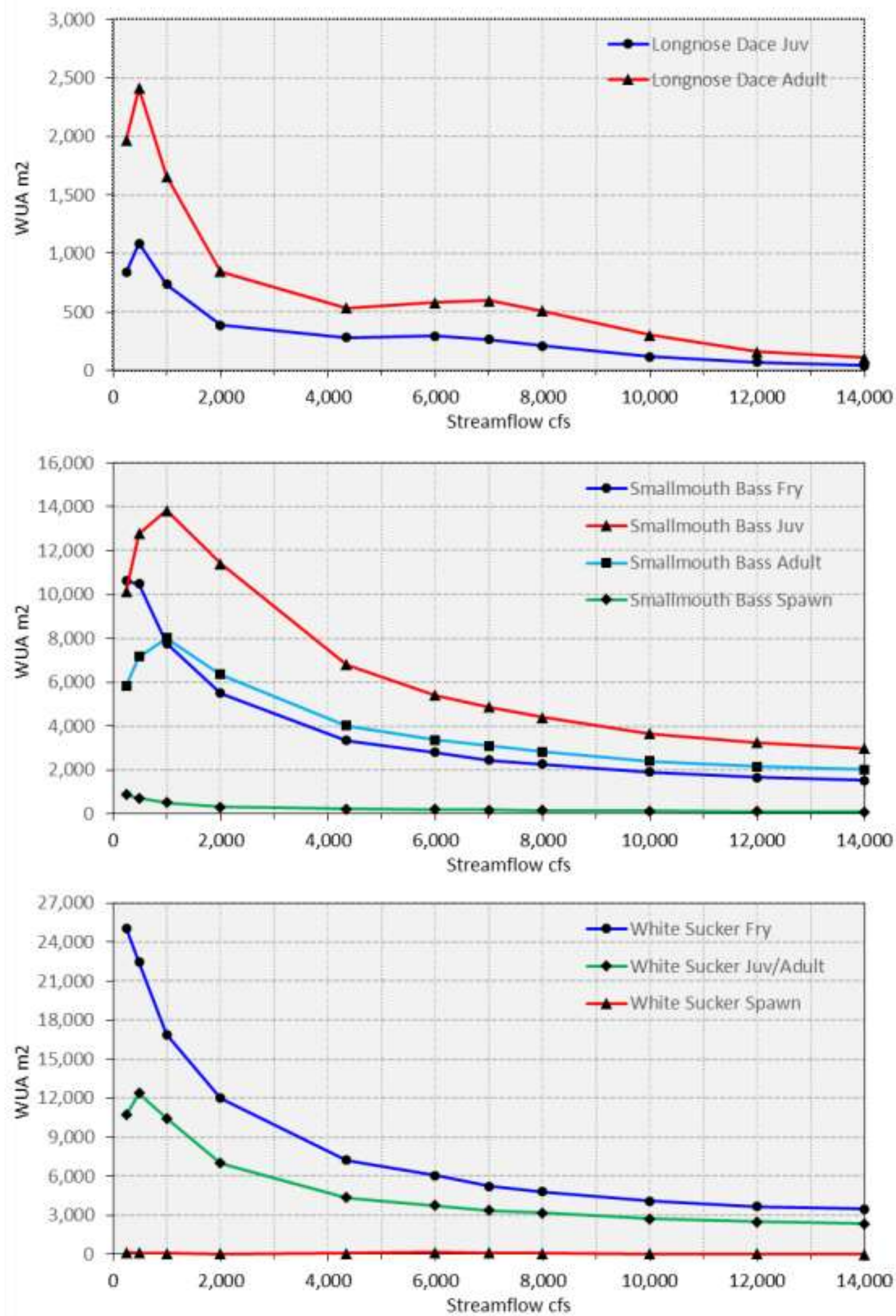
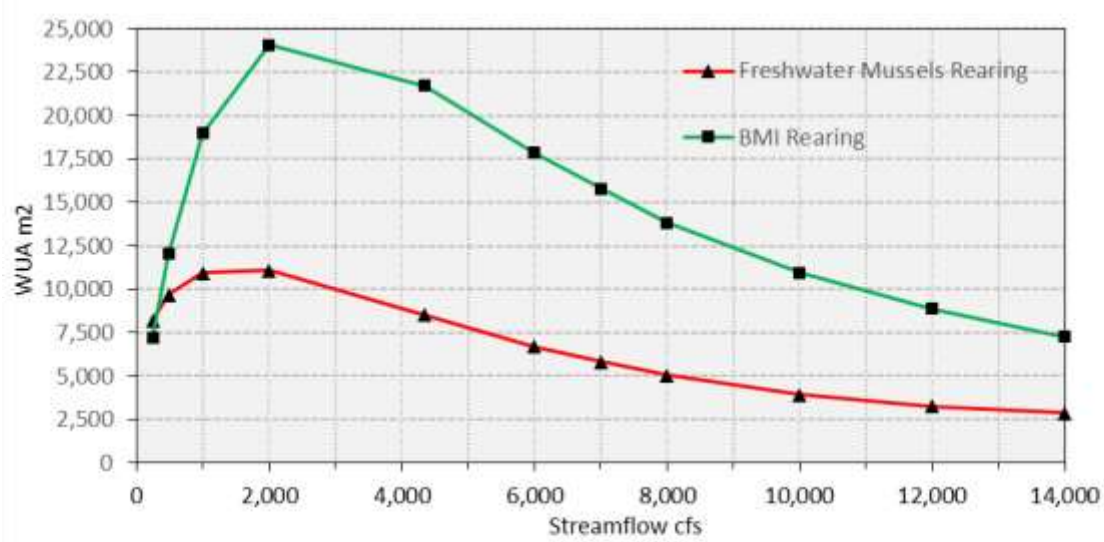


Figure E.7-20 (Continued)



The index of suitable habitat for American shad juveniles remained relatively high (>10,000 m^2) at flows between 250 cfs and 2,000 cfs, with declining suitability to a minimum (3,641 m^2) at the maximum modeled flow of 14,000 cfs. The suitability index for shad spawning stayed high (>10,000 m^2) over a wider range of flows (1,000-8,000 cfs), with minimum (~6,700 to ~5,700 m^2) at the lowest and the highest modeled flows, respectively. Most suitable habitat for both life stages occurred in the upper half of the modeled reach.

The habitat index for spawning by river herring was highest at 3,110 m^2 at the lowest modeled flow (250 cfs), then progressively declined to 490 m^2 as flows increased to 14,000 cfs. Virtually all of the estimated habitat was of low suitability, due to the low suitability (0.1) for all rocky substrates.

As shown above, benthic macroinvertebrates showed the highest estimates of WUA of all species groups, with a maximum of 24,062 m^2 at 2,000 cfs, and maintained high habitat values (>10,000 m^2) from 500 cfs to 10,000 cfs.

In most cases the habitat indexes for each species and life stage showed maximum suitable habitat at relatively low flows through the Bypass Reach. Thirteen of the 17 assessments produced maximum WUA at flows of 1,000 cfs or less, with 3 other species/life stages (lamprey spawning, freshwater mussels, and BMI rearing) reaching maximum WUA at 2,000 cfs, and one species/life stage (shad spawning) showing maximum habitat at a higher flow (4,345 cfs). This result is primarily due to the steep, bedrock dominated habitat that characterizes the Bypass Reach.

Canal System

The principal canals in the system are the Pawtucket Canal and the Northern Canal. Smaller canals lead off these two major canals. The canals vary in width from 40 to 120 feet. The walls are of granite, ledge, or concrete. The canal beds consist of ledge, concrete, or wood-planked virgin soil (Boott 2017).

Flow enters the canal system upstream of the Pawtucket Dam via the Pawtucket Canal and is controlled by the Guard Lock and Gates Facility. The nominal flow capacity of the downtown canal system via the Pawtucket Canal and the Guard Lock and Gates Facility is approximately 2,000 cfs.

The Northern Canal is approximately 2,200 feet long, with masonry or bedrock lining its complete length. The first 1,000 feet combines masonry walls and an earth dike (with masonry core) as the river wall. The second length is a dressed masonry gravity structure to the site of the E.L. Field Powerhouse. This structure is approximately 30 feet in height (Boott 2017).

E.7.3.1.3 Fish Assemblage

The Merrimack River is home to a diverse assemblage of fish species, including both cold water and warm water species. During the last 150 years, over 15 non-indigenous species such as largemouth bass (*Micropterus salmoides*), smallmouth bass (*M. dolomieu*), walleye (*Sander vitreus*), common carp (*Cyprinus carpio*), rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*), various catfish species (*Ictalurus* spp.) and goldfish (*Carassius auratus*) have successfully established themselves through human introduction within the Merrimack River. The Merrimack River basin is home to approximately 50 species of fish; nine of which are anadromous (Stolte 1982 as cited in Technical Committee for Anadromous Fishery Management of the Merrimack River Basin [Technical Committee] 1997). The slower-moving, ponded reaches within the basin contain the majority of the warm water species, while those areas having steeper gradients contain the majority of the cold-water species (Technical Committee 1997).

Common freshwater game species currently found in the Lower Merrimack River include yellow perch (*Perca flavescens*), chain pickerel (*Esox niger*), northern pike (*E. lucius*), brown bullhead (*Ameiurus nebulosus*), smallmouth and largemouth bass, walleye, common carp and Centrarchid sunfishes (Lower Merrimack River Local Advisory Committee [LMRLAC] 2008).

2019 Fish Assemblage Study

In 2019, a Fish Assemblage Study was conducted at the Project to characterize the fish assemblage in the Project's impoundment and bypass reach (NAI 2021d). Sampling locations in the impoundment and bypass reach were randomly selected and weighted proportional to mesohabitat type frequency.

Fish community data in the impoundment were collected from twelve 500-meter sample units during spring (June 24-26), summer (August 19-21), and fall (October 28-30) nights of 2019 (total of 36). At each sample unit, boat electrofishing[10] was conducted over a 500-meter reach of shoreline at depths less than 10 feet, an experimental gill net[11] was set in areas with adequate water depths (>8ft) and flow conditions for 4 hours, and two

[10] Boat electrofishing used 4.0 amps of pulsed DC current.

[11] Gillnets were eight feet deep and constructed of four 25-ft panels of increasing mesh size (1.0, 2.0, 3.0, and 4.0-inch stretch mesh).

minnow traps[12] were set to sample deeper habitats (>10ft deep) for 4 hours simultaneously with the gill nets (NAI 2021d).

Fish community data in the bypass reach was collected from three 50-meter sample units during the spring (June 28), summer (August 27), and fall (October 21) of 2019 (total of 12). Due to safety and gear limitations, sampling was not conducted in: (1) the reach from the Pawtucket Dam downstream to the School Street Bridge (also known as Mammoth Road); and (2) the lowermost section of the bypass channel downstream of the Northern Canal surge gate. At each sample unit daytime backpack electrofishing[13] was conducted during minimum flows.

Fish collected from the impoundment and bypass reach were identified to the lowest possible taxonomic classification, enumerated, measured to total length (to the nearest millimeter), and weighed (to the nearest gram). If large numbers of small fish (i.e., young-of-year [YOY] or small cyprinid species) were captured, length and weight information was collected from the first 25 individuals within the sample and the remaining individuals were grouped, enumerated, and batch weighed (NAI 2021d).

In the impoundment, a total of 1,847 individuals and 22 fish species were collected during the sampling efforts in the impoundment. Spottail shiner (*Notropis hudsonius*) (23.0%), redbreast sunfish (*Lepomis auratus*) (20.5%) and smallmouth bass (12.3%) were the three most numerically abundant species within the impoundment. Spottail shiners were the most abundant species in the spring (27.6% of seasonal catch) and fall (33.9% of seasonal catch) sampling, whereas redbreast sunfish were the most abundant species in the summer sampling (27.1% of seasonal catch).

Through the impoundment sampling, centrarchid species were the most abundant within impoundment habitat with redbreast sunfish (24.2%), pumpkinseed (*Lepomis gibbosus*) (14.2%), and smallmouth bass (12.5%) representing the three most abundantly collected species. Spottail shiner were the most abundantly sampled fish species in the pool (28.4%) and run (46.3%) habitat areas.

The majority of catch in the impoundment were obtained via boat electrofishing, where a total of 1,792 fish and 20 species were collected. Spottail shiner, redbreast sunfish, and smallmouth bass were the most frequently collected species during boat electrofishing efforts. Total boat electrofish catch was fairly consistent across seasons. A total of 55 fish and 15 species were collected using gill nets. Yellow bullhead (*Ameiurus natalis*) were the most collected species and the majority of catch was recorded during the summer season. No fish were collected with minnow traps.

In the bypass reach, a total of 526 fish and fourteen fish species were collected. Fallfish (*Semotilus corporalis*) (39.9%), smallmouth bass (20.3%) and spottail shiner (16.7%)

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[12] Traps were 2.5 feet long galvanized wire mesh (0.25 square inch) cylinders with two entry fykes.

[13] Halltech Aquatic Research Model HT2000B/MK5, battery-powered backpack electrofishers with ring probes and rattail cathodes were used for sampling. The backpack units were set at 550 volts at 100 Hertz (Hz). A fine mesh seine was anchored at the downstream end of the 50-m sample unit. A pair of backpack electrofishing units and four technicians moved in a downstream direction towards the seine while actively netting stunned fish and kicking the substrate to drive additional stunned fish towards the collection net.

were the three most numerically abundant species. Spottail shiner were most abundant during the spring (48.8%) and fallfish during the summer (55.0%) and fall (39.9%).

In the bypass reach, fallfish were the most abundant fish collected within the pooled habitat, which represented 47% of the total catch. Smallmouth bass were the most abundant fish species collected in the ledge habitat in the bypass reach, which represented 60.6% of the total catch from that habitat. Close to 14 percent of the total catch in ledge habitat were American eels (*Anguilla rostrata*).

Table E.7-14 provides a comparison of the percent composition of all species collected during the 2019 Fish Assemblage Study. In comparison to the historical fish community in the vicinity of the Project, one new species was collected during the 2019 sampling effort, the channel catfish (*Ictalurus punctatus*). An additional 19 fish species have been observed historically in the Project vicinity, which are presented in Table E.7-15.

Table E.7-14. Fish Assemblage Observed During the 2019 Sampling of the Impoundment and Bypass Reach

Common Name	Scientific Name	Percent Composition	
		Impoundment	Bypass Reach
Alewife	*Alosa pseudoharengus*	6.1	-
American Eel	*Anguilla rostrata*	0.9	6.3
Black Crappie	*Pomoxis nigromaculatus*	0.3	-
Bluegill	*Lepomis macrochirus*	6.6	0.6
Brown Trout	*Salmo trutta*	-	0.2
Channel Catfish	*Ictalurus punctatus*	0.1	-
Common Carp	*Cyprinus carpio*	0.3	-
Fallfish	*Semotilus corporalis*	7.7	39.9
Golden Shiner	*Notemigonus crysoleucas*	0.7	-
Largemouth Bass	*Micropteris salmoides*	2.2	0.4
Sunfish, species unidentified	*Lepomis* spp.	0.2	0.2
Longnose Dace	*Rhinichthys cataractae*	-	0.4
Margined Madtom	*Notorus insignis*	0.5	3.2
Pumpkinseed	*Lepomis gibbosus*	8.4	-
Redbreast Sunfish	*Lepomis auritus*	20.5	2.5
Rock Bass	*Ambloplites rupestris*	0.4	-
Sea Lamprey	*Petromyzon marinus*	1.1	0.2
Smallmouth Bass	*Micropterus dolomieu*	12.3	20.3
Spottail Shiner	*Notropis hudsonius*	23	16.7

Common Name	Scientific Name	Percent Composition	
		Impoundment	Bypass Reach
Tessellated Darter	*Etheostoma olmstedi*	1.7	1.9
Walleye	*Sander vitreus*	0.1	-
White Perch	*Morone americana*	0.1	-
White Sucker	*Catostomus commersoni*	3	6.3
Yellow Bullhead	*Ameiurus natalis*	2.9	1
Yellow Perch	*Perca flavescens*	1.1	-

Source: NAI 2021d

Table E.7-15. Additional Fish Species Observed Historically at the Project

Common Name	Scientific Name
American shad	*Alosa sapidissima*
Atlantic salmon	*Salmo salar*
Banded killifish	*Fundulus diaphanus*
Banded sunfish	*Enneacanthus obesus*
Blacknose dace	*Rhinichthys atratulus*
Blueback herring	*Alosa* aestivalis
Bridle shiner	*Notropis bifrenatus*
Brook trout	*Salvelinus fontinalis*
Brown bullhead	*Ameiurus nebulosus*
Chain pickerel	*Esox niger*
Common shiner	*Luxilus cornutus*
Creek chubsucker	*Erimyson oblongus*
Gizzard shad	*Dorosoma cepedianum*
Goldfish	*Carassius auratus*
Northern pike	*Esox lucius*
Redfin pickerel	*Esox americanus*
Slimy sculpin	*Cottus cognatus*
Striped bass	*Morone saxatilis*

Common Name	Scientific Name
Swamp darter	*Etheostoma fusiforme*
White catfish	*Ameiurus catus*

Sources: Hartel et al. 2002; Merrimack River Technical Committee 1997.

E.7.3.1.4 Migratory Species and Fish Passage

Overview

Fish passage at the Lowell Hydroelectric Project is managed in accordance with the CFPP. The CFPP includes details of operational measures undertaken by Boott to protect upstream and downstream migrating anadromous fish. Upstream and downstream fish passage facilities at the Project include a fish lift and downstream fish bypass at the E.L. Field Powerhouse and a vertical-slot fish ladder at the Pawtucket Dam. The fish passage facilities at the Project were designed in consultation with the USFWS and current fish passage operations are supervised by both state and federal fishery agencies per the CFPP.

In accordance with the CFPP, Boott is required to begin operating the fish passage facilities at the Lowell Project when a cumulative total of 50 American shad (*Alosa sapidissima*) or 200 river herring (*A. pseudoharengus*) are passed at the downstream Lawrence Hydroelectric Project (FERC No. 2800). Termination of upstream fish passage operations at the end of the upstream passage season is determined each year in consultation with the MRTC, and typically occurs in early to mid-July. Additionally, in accordance with the CFPP, Boott is required to operate the downstream bypass facility from April 1 through July 15 and from September 1 through November 15 (Cleantech Analytics 2017). Under the CFPP, Boott provides annual post-season updates to the MRTC. Fish are capable of bypassing the Project's entire canal system via the Merrimack River and use the existing upstream and downstream fish passage facilities at the Pawtucket Dam and E.L. Field Powerhouse. There are no exclusionary measures at the entrance of the Project's canal system. However, in the CFPP, Boott included an operational protocol to pass additional flows through the canal system in the rare instance where the Northern Canal needs to be dewatered to conduct repairs or maintenance on the main powerhouse during downstream fish passage season (Cleantech Analytics 2017). This provision has been implemented only once during the term of the license, to facilitate repairs to the Northern Canal wall in 1996.

As currently provided in the CFPP, the fish lift has historically been the primary route of upstream passage at the project, whereas the ladder has typically been operated only during periods of higher flow when spillage at the dam may attract upstream migrants toward the bypass reach. In recent years, Boott and the MRTC have tested the success of passage through the ladder under normal, non-spill conditions with very favorable results. Beginning in 2018 Boott has agreed to operate both the lift and the ladder throughout the fish passage season, in exchange for agency support of LIHI certification of the Project.

As a component of the CFPP, Boott collects information regarding the abundance of diadromous fishes using the upstream fishways annually. This activity is a joint monitoring effort to inform the MRTC that manages these fishery resources. MADFW and Boott staff work cooperatively to record diadromous fish counts at the E. L. Field Powerhouse fish lift throughout the upstream migration season. Beginning in 2017, fish count records also were kept at the Pawtucket Dam fish ladder. Boott provides a summary of these counts as part of its annual fishway operations report to the MRTC (Table E.7-16).

The CFPP is based on several fisheries studies conducted at the Project and experience gained at the Project since the installation of the Project's fish lift and fish bypass facilities. The CFPP was developed in consultation with the resource agencies, and many of the agencies' recommendations have been incorporated into the CFPP. Currently, Boott is coordinating with the USFWS and University of Massachusetts, Amherst, in upstream and downstream American eel passage studies at the Project. Since 2013 Boott has actively worked with USFWS to assess and improve upstream eel passage at the Pawtucket Dam.

In 2016, Boott purchased new radio telemetry equipment to assist the USFWS monitoring at three sites to assess the downstream movement of radio tagged adult eels released at the Merrimack River Project upstream (Cleantech Analytics 2017). In 2017 Boott deployed telemetry equipment at six locations at the Lowell Project and two locations at the Lawrence Project to again track the movement of radio-tagged eels released at the Merrimack River Project through the Lowell Project facilities. As discussed in more detail below, each of the fourteen radio-tagged eels determined to have successfully passed downstream of the Lowell Project, with the majority of individuals passing via the turbines and the remainder passing by spill.

The priority species for management at the Lowell Project are the catadromous American eel and three anadromous Alosidae species, American shad (*Alosa sapidissima*), blueback herring (*Alosa aestivalis*), and alewife (*Alosa pseudoharengus*). Juvenile and adult American eel upstream and downstream migration periods overlap. Juveniles ascend beginning in May and continue through October. The adult outmigration period begins in late summer and lasts through November. The peak outmigration period is October through mid-November (Boott 2018).

Adult American shad and river herring ascend the Merrimack River from May through early July. The peak period is highly dependent on water temperature and total river discharge. The juvenile outmigration period is in the fall (September through November) and is also highly dependent on ambient water temperature and river discharge conditions (Boott 2018).

Outmigrating fish encountering the Pawtucket Dam can: (1) pass through the Pawtucket Gatehouse and enter the power canal; (2) pass downstream over Pawtucket Dam via spill; or (3) enter the Pawtucket Canal and navigate downstream via the downtown canal system. Individuals which enter the Northern Canal can pass downstream via one of the two turbine units at the E.L. Field Powerhouse, utilize the downstream bypass, or pass via the surge gate (operated only in the event of a station trip).

Table E.7-16. Lowell and Lawrence Diadromous Fish Passage Counts Since 1983

Year	River Herring (Lawrence)	River Herring (Lowell)	American Shad (Lawrence)	American Shad (Lowell)	Atlantic Salmon (Lawrence)	American Eel (Lowell)	American Eel (Lawrence)
1983	4.794		5.629		114		
1984	1,769		5,497		115		
1985	23,112		12,793		213		
1986	16,265		18,173	1,630	103		
1987	77,209		16,909	3,926	139		
1988	361,012	56,739	12,359	1,289	65		
1989	387,973	137,296	7,875	940	84		
1990	254,242	9,888	6,013	443	248		
1991	379,588	6,920	16,098	428	332		
1992	102,166	32,501	20,796	6,491	199		
1993	14,027	4,315	8,599	1,679	61		
1994	88.913	33.735	4.349	383	21		
1995	33.425	11.848	13.861	5.255	34		
1996	51	51	11.322	400	76		
1997	403	403	22.661	4.446	71		
1998	1.362	13	27.891	4.159	123		
1999	7.898	2.930	56.461	16.347	185		
2000	19,405	673	72,800	12,716	82		
2001	1,550	58	76,717	7,740	83		
2002	526		54,586	5,283	56		
2003	10,866	194	55,620	6,580	147		
2004	15,051	7,448	36,593	11,028	129		
2005	99	201	6,382	716	34		
2006	1,257	27	1,205		91		
2007	1,169		15,876	1,653	74		
2008	108		25,116	4,050	119		
2009	1,456	139	23,199	2,267	81		
2010	518	43	10.442	490	85		
2011	740	228	13.835	831	402		
2012	8.992	1.809	21.396	1.728	137		6.969
2013	17.359	13.490	37.149	9.756	22		915
2014	57.213	23.610	38.107	3.357	75	166	1.788
2015	128,692	31,323	89,467	20,937	13	2,647	8,124

Year	River Herring (Lawrence)	River Herring (Lowell)	American Shad (Lawrence)	American Shad (Lowell)	Atlantic Salmon (Lawrence)	American Eel (Lowell)	American Eel (Lawrence)
2016	417,240	287,343	67,528	11,439	6	328	1,981
2017	91,616	5,656	62,846	5,086	5	1,981	17,738
2018	276,449	311,867	25,081	14,046	10	*	267,353
2019	43,108	43,871	19,450	2,201	15	*	81,179
2020	87,150	181,979	52,239	8,449	1	974	93,058
TOTAL	**2,934,773**	**1,357,876**	**1,072,920**	**178,169**	**3,850**	**6,096**	**479,105**

*continuously ran fish ladder in 2018 and 2019 was primary upstream passage for eels, accurate quantity was unavailable without trapping.
Source: Boott 2018; K. Webb, Boott Hydropower, personal communication, March 19, 2018

Historical Studies

Multiple studies have been conducted at the Lowell Project to assess the movement behavior, passage route use, and survival of migratory fish species during the past three decades. Use and efficiency studies of the E.L. Field Powerhouse fish lift by American shad were conducted in 1999 and 2000 by Boott and by Alden Research Laboratory in 2011. The earlier studies led to significant modifications and upgrades of those facilities that improved the passage efficiencies of American shad. In addition, a 1988 acoustic telemetry study performed by RMC Environmental Services (RMC) of adult American shad movement through the Northern Canal demonstrated delayed movement through the Pawtucket Gatehouse, as well as incidental information regarding downstream passage routes for post-spawning individuals (RMC 1988). In a follow-up study in 1991 by NAI found similar findings as the 1988 adult American shad telemetry study (NAI 1991a).

Downstream bypass effectiveness studies in 1991 and subsequent studies in 1994 and 1995 by NAI yielded information regarding the use of the Project's bypass reach. This information led to phased modifications of the bypass which increased its use and efficiency at passing juvenile Alosids downstream. Similar studies were performed for Atlantic salmon smolts in 1996 and 2003 by NAI. A 2005 USFWS radio telemetry study provided information regarding American shad movement behavior between the downstream hydroelectric station, Lawrence, and the Lowell facilities. The upstream passage of American shad was also assessed at the Lowell Project in 2011 by Alden Research Laboratory, Inc, with additional analyses performed in 2013. Most recently, a study performed in 2017 by NAI yielded information regarding the downstream migratory behaviors of American eel in the Lowell Project.

During 2019, three additional fish passage studies were conducted at the Lowell Hydroelectric Project as outlined in the RSP, which are described further below along with more specific details on the historical studies.

American Eel Passage

The downstream passage for silver-phase American eels was evaluated by NAI in 2017. As part of that evaluation, fourteen radio-tagged eels passing downstream of the Amoskeag Project (the next hydroelectric facility upstream of Lowell in New Hampshire) were detected at Pawtucket Dam and thirteen of the fourteen study eels arriving at Lowell were subsequently detected downstream at Lawrence. The transit times between Amoskeag and Pawtucket Dam ranged from 10 – 244 hours. Eel passage events occurred primarily between sunset and sunrise via the turbines (eight) and over Pawtucket Dam (five); one individual was not detected at the passage detection fields at Lowell but was detected at the Lawrence Project. In addition, the E.L. Field Powerhouse bypass was not used as a downstream passage route.

More recently, a radio-telemetry assessment of the downstream passage success for adult silver-phase American eels was performed during the fall of 2019, pursuant to the SPD (NAI 2021a). Monitoring of outmigrating adult American eels focused on the evaluation of movement through the Project impoundment, residence time immediately upstream of the Pawtucket Dam and prior to passage, passage route utilization and estimation of downstream passage survival at the Project.

Following the release of 102 radio-tagged individuals[14] into the Merrimack River 11 miles upstream of the Lowell impoundment, their movements were monitored using a series of stationary radio-telemetry receivers in place at the Project[15] to inform on general movements, distribution among available passage routes and Project passage success (NAI 2021a).

Radio-tagged eels moved through the existing 23-mile-long Project impoundment in a median duration of 2.1 days. Upon initial detection at the Pawtucket Dam, the median duration of time spent immediately upstream of the dam structure was 0.4 hours with 94% passing downstream within the first 24 hours of their initial detection. Closer examination of the total residence time for radio-tagged eels indicated that the 95% of individuals passing through the Pawtucket Gatehouse did so in 30 minutes or less and upon entry into the Northern Canal the median residence duration prior to downstream passage was 0.2 hours (NAI 2021a).

During the 2019 evaluation there was no detected use of the downtown canal system by outmigrating radio-tagged eels. The majority of radio-tagged individuals passed through the Pawtucket Gatehouse and approached the E.L. Field powerhouse with 92.5% eventually passing downstream via the turbine units (Table E.7-17). Use of the existing downstream bypass system was limited to only two individuals. Downstream passage at the Project peaked during late October with all passage events completed by October 31. The majority of downstream passage events occurred during the evening and overnight hours (NAI 2021a).

[14] Normandeau Associates simultaneously conducted an additional downstream adult eel passage study at the Merrimack River Project (FERC No. 1893) during fall 2019. A total of 60 eels were radio-tagged during that assessment and were also monitored for passage at Lowell. Results from that group of eels at Lowell and points downriver have been incorporated into this report.

[15] 12 monitoring stations total.

The high number of radio-tagged individuals that passed downstream via the turbine units likely resulted from drier than normal conditions in the region. Only two major spill events, associated with increases in river flows, occurred during the monitoring period. The first major spill event occurred from approximately October 29 to November 5 and the second occurred towards the end of the passage season (~November 25) (NAI 2021a). The timing of the spill events occurred primarily after the peak of downstream passage at the Project. Under normal conditions, the frequency of spill events would be greater due to more frequent increases in river flows, thereby increasing the downstream passage of individuals over the dam and decreasing individuals passing downstream via the turbine units.

Downstream passage survival was estimated for all radio-tagged eels from the point of initial detection upstream of the Pawtucket Dam downstream to Lawrence. This resulted in an estimated downstream passage survival for silver-phase American eel at Lowell of 75.5% (75% Confidence Interval [CI] = 71.4%-79.6%). This estimate of downstream passage survival for adult eels at the Project includes any background (i.e., natural) or tagging-related mortality for the species in the reach from approach to the Pawtucket Dam to Lawrence. As a result, this estimate should be viewed as a minimum estimate of total project survival (i.e., due solely to project effects) for adult eels at the Project. Due to the limited distribution of downstream passage route selection, route-specific estimates of passage were developed for only individuals using turbine units at the E.L. Field powerhouse (n = 136; 75.0% survival; 75% CI = 70.6%-79.4%). The limited number of radio-tagged eels passing the Project via spill or the downstream bypass system were all determined to have successfully approached the Lawrence Project following downstream passage at Lowell (NAI 2021a).

Table E.7-17. Downstream passage route selection for radio-tagged eels released upstream of the Lowell project boundary and upstream of Garvins Falls Dam during the fall 2019 downstream passage assessment.

Release Location	Release Date	Lowell Downstream Passage Route					
		Did not Detect	Did Not Pass	Unknown	Turbine	Spill	Bypass
Garvins Falls	9-Oct	7	0	1	11	1	0
Garvins Falls	11-Oct	2	1	0	15	1	1
Garvins Falls	15-Oct	6	0	0	13	1	0
Garvins Falls	All	15	1	1	39	3	1
Lowell	9-Oct	0	0	1	19	0	0
Lowell	11-Oct	0	0	0	19	0	1
Lowell	16-Oct	0	0	1	18	1	0
Lowell	18-Oct	0	0	0	20	0	0

Release Location	Release Date	Lowell Downstream Passage Route					
		Did not Detect	Did Not Pass	Unknown	Turbine	Spill	Bypass
Lowell	23-Oct	0	0	1	21	0	0
Lowell	All	0	0	3	97	1	1
All		15	1	4	136	4	2
Percent Utilization			0.7%	2.7%	92.5%	2.7%	1.4%

Source: NAI 2021a.

The Fish Passage Survival Study (NAI 2021f) addressed the qualitative classification of impingement, entrainment, and the probability of turbine passage survival at the Project using a review of relevant biological criteria and physical Project characteristics for American eel. The study used a turbine blade strike analysis (TBSA) model, which relied on recent USFWS guidance on the use of a varied correlation coefficient for American eel, to calculate survival estimates through the E.L. Field Kaplan units. The estimated range of survival for eels passing downstream through the E.L. Field turbines ranged from 71-39 percent, with the predicted rate of survival for adult eels decreasing as body size/length increased (Table E.7-18). In the case of adult eels, the TBSA model tended to underestimate turbine survival when compared to empirical results from the Downstream American Eel Passage Assessment.

Table E.7-18. TBSA predicted survival estimates for adult American eels at the E.L. Field powerhouse.

Species/Life Stage	Size potentially encountered the region (in)	Body Length (inches)						
		21	24	28	32	36	40	45
American eel (Adult)	25-41	71.20%	67.30%	61.80%	56.50%	51.70%	46.00%	39.10%

Juvenile Alosine Downstream Passage

The downstream passage of juvenile alosines has been studied at the Lowell Project a number of times since 1990. After conducting a mark and recapture study in the fall of 1990 to determine the relative efficiency of its fish bypass system at passing juvenile clupeids, it was determined that because water depth in the vicinity of the E.L. Field Powerhouse's bypass is greater than 30 feet, the 91-centimeter-deep bypass opening at the facility may be too shallow for the majority of fish to locate it (NAI 1991b). During this study, a total of 7,882 juvenile clupeids were captured in the bypass net between September 25 and October 23. Alewives comprised 95% of the catch, shad 4.5%, and blueback herring less than 0.5%. Modifications to the fish bypass at the E.L Field Powerhouse were subsequently completed, and downstream juvenile alosine passage was again examined during the fall of 1993 and 1994 to assess efficiency of the modified bypass opening. Both studies concluded that the modified bypass opening greatly improved passage efficiency, by approximately 30 percent (NAI 1994 and NAI 1995).

An evaluation of the potential impacts on the outmigration of juvenile alosines was conducted in the fall 2019 migration season using radio-telemetry as outlined in the RSP (NAI 2021b). Monitoring of outmigrating juvenile alosines focused on the evaluation of the residence time immediately upstream of the Pawtucket Dam and prior to passage as well as passage route utilization at the Project.

A total of 145 juvenile alosines[16] were tagged and released at mid-river locations approximately one mile upstream of the Pawtucket Gatehouse. Their subsequent downstream arrival and passage at the Project was monitored via a series of fixed-location telemetry receivers within the Lowell Project area.

Upon initial detection at the Pawtucket Dam, the median duration of time spent immediately upstream of the dam structure was 1.3 days with 42% passing downstream within the first 24 hours of their initial detection. Closer examination of the total residence time for radio-tagged juvenile alosines indicated that all individuals determined to have entered the Northern Canal passed through the Pawtucket Gatehouse in less than 30 minutes. Upon entry into the Northern Canal, the median residence duration prior to downstream passage was longer (22.0 hours; range = 0.2 hours to 4.7 days). Nearly 70% of all downstream passage events for radio-tagged juvenile alosines occurred within 48 hours of initial detection in the E.L. Field forebay. A statistically significant interaction was suggested between mid and high generation conditions in relation to passage failure from the E.L. Field forebay. The presence of higher generation flows increased the probability that a radio-tagged individual would approach downstream passage options in the power canal (i.e., turbines or downstream bypass) and decreased the passage attempt relative to lower generation flows.

During the 2019 evaluation, the majority of radio-tagged individuals passed through the Pawtucket Gatehouse and approached the E.L. Field Powerhouse (Table E.7-19). Of the individuals which approached the E.L. Field Powerhouse and had a known downstream passage route, 83% eventually passed downstream via the turbine units. Use of the existing downstream bypass system was estimated at 17%.

[16] The FERC-approved RSP indicated that a total of 150 radio-tagged juvenile alosines shall be used for the study. Five of the transmitters purchased for this study could not be activated. As a result, a total of 145 radio-tagged juvenile alosines were released and assessed for downstream passage at the Project. There were no additional variances from the FERC-approved study plan.

Table E.7-19. Downstream passage route selection and percent utilization of route options after detection at Station 21 for radio-tagged juvenile alosines released upstream of Pawtucket Dam during the fall 2019 downstream passage assessment.

Release Date	Lowell Downstream Passage Route						
	Did not Detect	Did Not Pass	Downtown Canal System	Spill	Bypass	Turbine	Unknown
9-Oct	0	2	1	1	5	6	0
11-Oct	0	2	1	0	4	8	0
13-Oct	1	3	0	1	4	4	1
14-Oct	1	1	1	0	1	10	1
15-Oct	0	2	0	2	2	8	1
16-Oct	0	0	0	6	0	7	2
17-Oct	0	2	0	2	0	9	3
18-Oct	0	2	0	0	0	13	0
23-Oct	1	3	0	0	1	11	1
24-Oct	0	4	0	1	0	6	0
All	3	18	3	13	17	82	9
Percent Utilization		12.7%	2.1%	9.2%	12.0%	57.7%	6.3%

Source: NAI 2021b.

During the Revised ISR Meeting on October 15, 2020, FERC and NAI discussed the models at the gatehouses and the correlations between flow and temperature. NAI stated they could likely make changes to the model to further explore those variables.

The Fish Passage Survival Study (NAI 2021f) used the TBSA desktop tool to estimate total project survival for juvenile alosines at the Project. Estimates of turbine passage were inversely related to body length for each species/life stage considered with highest survival estimated for small juvenile shad or herring at 2 inches of length (~99%) (Table E.7-20).

Table E.7-20. TBSA predicted survival estimates for juvenile American shad and river herring at the E.L. Field powerhouse.

Species/Life Stage	Size potentially encountered the region (in)	Body Length (inches)		
		2	4	6
American shad (Juv)	2-6	98.6%	97.2%	95.9%
River herring (Juv)	1.5-6	98.6%	97.2%	95.9%

An empirical estimate of juvenile alosine survival was not derived during the 2019 Juvenile Alosine Downstream Passage Assessment at Lowell. The model required input of available downstream passage routes and an estimate of their proportional usage. Those rates were obtained from the 2019 study which estimated route usage for individuals passing the project via known mainstem routes as 11.6% via spill, 15.1% via the downstream bypass, and 73.2% via the E.L. Field turbine units. These observed route selection probabilities were imported into a multi-route TBSA model to evaluate the predicted whole-station survival for a normally distributed population of 1,000 3.5 inch (S.D. ±1.0 inches) fish. For non-turbine routes (e.g., downstream bypass or spill), an estimate of passage mortality was required and was based on the empirical estimates obtained for adult alosines at the Project (12% at the downstream bypass and 11% via spill). Using this methodology, total project survival at Lowell for juvenile alosine-sized fish is estimated at 94.8%. Passage failures were attributed to fish passing downstream via the turbines (2.1% of total losses) and the downstream bypass facility/spill (3.1% of total losses).

Upstream and Downstream Adult Alosine Passage

Upstream and downstream passage of alosines at the Lowell Project has been evaluated several times since 1990. Downstream passage routes of radio-tagged American shad were evaluated in 1990. Approximately half of the shad tagged during their upstream migration returned to the Project site and 53% proceeded to pass through the E.L. Field Powerhouse, 22% passed using the fish bypass, 9% entered the Pawtucket Canal, and 13% spilled over the Pawtucket Dam. The study also indicated that the losses of adult shad upriver from the Lowell Project was consistent with shad runs in other rivers (NAI 1991a).

The internal efficiency of the Lowell Project fish lift at passing adult American shad upstream to spawn was evaluated in 1996 using underwater cameras. Study results indicated that internal fish lift efficiency for shad at the Project was low for both flows evaluated (50 cfs and 90 cfs), probably due to the low flow velocities inside the fish lift entrance channel, especially upstream of the crowder gates. With higher flows and velocities inside the fish lift entrance channel, fewer shad dropped out of the system and internal lift efficiency improved. However, even with the increased flow, most of the shad observed approaching the crowder gates did not pass through them. A similar study was performed in the spring of 1999, in which the upstream passage season was exceptionally successful at passing the highest number of shad since the fish lift was commissioned. Four hundred percent more individual shad were lifted in the spring 1999 season compared to both 1997 and 1998. The average internal lift efficiency (42%) achieved at the Lowell Project during the 1999 fish lifting season represented a substantial improvement over the previous results, increasing over seventeen-fold compared to results achieved in 1996. Additional upstream fish lift internal efficiency studies were performed in 2000 and 2001. Both studies concluded that the crowder gate opening has a significant effect on internal fish lift efficiency. Brail camera results, which are most comparable to previous studies at Lowell and Lawrence, clearly show that internal efficiency at Lowell had substantially improved due to the fish lift modifications and was comparable to efficiencies experienced at Lawrence.

The upstream passage of American shad was also assessed at the Lowell Project in 2011 by Alden Research Laboratory, Inc. Adult shad passage success or impediments and overall fish migration patterns from the Lawrence Hydroelectric Project into the Lowell tailrace and into the Lowell project's fish lift hopper was evaluated during this study. The acoustic telemetry results indicated that 57% of shad that pass the Lawrence Hydroelectric Project reach the Lowell tailrace. Only three individual fish were detected as entering the riverside fish lift entrance. Additional analysis in 2013 by Blue Leaf Environmental concluded that shad did not spend long periods of time holding in a specific position within the tailrace or reside in areas outside of the established pattern of movement. Shad were also determined to move in a clockwise and counter-clockwise direction along both walls in the tailrace, contrary to the 2011 study which suggested shad move in a "U" shaped swimming pattern following the edges of the tailrace and the wall of the powerhouse.

An evaluation of the upstream and downstream passage effectiveness for adult alewives and American shad was conducted during the spring 2020 passage season (May through June) (NAI 2021c). Merrimack River conditions were considered normal or low for the majority of May, and low for most of the month of June. The E.L. Field fish passage facilities (i.e., upstream fish lift and downstream fish bypass) were operated throughout the study period and those turbine units were in operation for the duration of the study period. Two major spill events, associated with increases in river flows, occurred during the early portion of the monitoring period (May 7 and May 18). Flows to the downstream canal system were limited during both months as Boott suspended operation of the generating units in that system prior to the onset of the study due to overriding safety concerns.

Following the release of radio-tagged individuals[17] into the Merrimack River both upstream and downstream of the Lowell facility, their movements were monitored using a series of stationary radio-telemetry receivers in place at the Project as well as at several additional stationary monitoring receivers installed at bank-side locations upstream and downstream of the Project to inform on general movements, distribution among available passage routes and Project passage success.

Of the dual-tagged[18] adult alewives released downstream of the Project (150 individuals were dual-tagged and 204 were PIT-tagged), 85% were determined to have approached Lowell and were available to assess passage effectiveness of either the E.L. Field Powerhouse fish lift or the Pawtucket Dam fish ladder. The duration of time for fish to move upstream from the release location at Lawrence to Lowell was around one day for most dual-tagged adult alewives (median = 19.6 hours; 75th percentile = 28.6 hours). Following arrival downstream of the Project, 95% of dual-tagged adult alewives made at least one foray upstream towards either the fish lift or ladder. When examined by structure, 64% of dual-tagged alewives made at least one foray in the direction of the fish lift, 67% in the direction of the fish ladder, and 39% in the direction of the fish lift and fish ladder. The overall effectiveness of the E.L. Field fish lift for adult alewife passage during

[17] A total of 150 adult alewives and 150 adult American shad were radio-tagged and released upstream of the Pawtucket Dam for the purposes of evaluating downstream passage. A total of 354 adult alewives and 384 adult American shad were radio-tagged and released for the purposes of evaluating upstream passage.

[18] Dual- and PIT-tagged individual fish were analyzed separately due to poor conditions at Monitoring Station 20, which precluded effected monitoring of PIT-tagged individuals.

2020 was estimated at 43.9% (75% CI = 39.3-51.4%). The overall effectiveness of the Pawtucket Dam fish ladder for adult alewife passage during 2020 was estimated at 75.6% (75% CI = 69.2-82.2%).

Of the 150 radio-tagged adult alewives released upstream of Lowell, 83% approached the Pawtucket Dam and were available to evaluate downstream passage at the Project. The median upstream residence time prior to downstream passage was 2.0 days with 77% of individuals passing downstream in less than 96 hours after their arrival. The majority of individuals passed downstream of Lowell via the E.L. Field turbine units (52% of radio-tagged alewives) or utilized the downstream bypass (45% of radio-tagged alewives). Downstream passage survival was calculated as the joint probability of the three reach-specific survival estimates which encompasses the full section of the Merrimack River from Lowell downstream to Lawrence and resulted in an estimated downstream passage survival for adult alewives at Lowell of 76.5% (75% CI = 71.5%-80.5%). This estimate of downstream passage survival for adult alewives at Lowell included 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, this estimate should be viewed as a minimum estimate of total project survival (i.e., due solely to project effects) for adult alewives at the Project.

Of the 180 dual-tagged[9] adult American shad released downstream of the Project, 40% were determined to have approached Lowell and were available to assess passage effectiveness of either E.L. Field Powerhouse fish lift or the Pawtucket Dam fish ladder. An additional 47% of the dual-tagged shad exhibited upstream movement following tagging and release at Lawrence but did not move the full length of the Merrimack River reach between the two Projects. The median duration of time for shad to move upstream from the release location at Lawrence to Lowell was 64.5 hours (2.7 days). The vast majority those shad made one or more forays in the direction of the fish lift. Only a single dual-tagged shad was determined to have initiated an upstream ascent into the bypassed reach and in the direction of the fish ladder and two additional PIT-tagged shad entered the fish ladder. The overall effectiveness of the E.L. Field fish lift for adult American shad passage during 2020 was estimated at 30.4% (75% CI = 22.1-39.5%).

Of the 150 radio-tagged adult shad released upstream of Lowell, 79% approached the Pawtucket Dam and were available to evaluate downstream passage at the Project. The median upstream residence time prior to downstream passage was 3.9 days with 51% of individuals passing downstream in less than 96 hours after their arrival. The majority of individuals passed downstream of Lowell via the E.L. Field turbine units (26%), the downstream bypass (28%) or utilized the bypassed reach (38%). Downstream passage survival was calculated as the joint probability of the three reach-specific survival estimates which encompasses the full section of the Merrimack River from Lowell downstream to Lawrence and resulted in an estimated downstream passage survival for adult shad at Lowell of 70.0% (75% CI = 64.5%-74.6%). This estimate of downstream passage survival for adult shad at Lowell included 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, this estimate should be viewed as a minimum estimate of total project survival (i.e., due solely to project effects) for adult American shad at the Project.

The Fish Passage Survival Study (NAI 2021f) used the TBSA tool to estimate survival for American shad and river herring. The TBSA produced a range of survival estimates for American shad and river herring turbine survival through the Project's E.L. Field powerhouse Kaplan units. Within that range of estimates, the probability of mortality due to blade strike increased as body size increased. In the case of adult alosines, the TBSA model tended to overestimate turbine survival when compared to the 2019 empirical results from the Upstream and Downstream Adult Alosine Passage Assessment (NAI 2021c).

Table E.7-21. TBSA predicted survival estimates for juvenile American shad and river herring at the E.L. Field powerhouse.

Species/Life Stage	Size potentially encountered the region (in)	Body Length (inches)				
		8	12	16	20	25
American shad (adult)	15-23			89.0%	86.4%	83.1%
River herring (adult)	9-13	94.8%	91.8%	89.0%		

The Instream Flow Habitat Assessment and Zone of Passage Study (NAI 2021e) used River 2D (a two-dimensional hydraulic model) to assess the relationship between bypass flow and upstream passage through the bypassed reach. The zone of passage model was developed for three adult migratory species: American shad, blueback herring, and alewife. The 2.5 ft depth criteria for American shad showed that near full connectivity did not occur throughout the bypass reach until flows exceeded 4,000 cfs. This modeled lack of passage zones at low flows was largely due to the deep passage criteria for shad. Because the deep depth criteria may not be realistic for shad swimming through natural channels (as opposed to jumping weirs or ascending ladders), this analysis was re-run using 1.0 ft depth criteria, which is the depth criteria for river herring. Decreasing the depth criteria from 2.5 ft to 1.0 ft for shad resulted in almost continuous passage opportunities at just under 500 cfs, with multiple continuous pathways becoming available at flows of 1,000 cfs and above. Depth suitability for shad passage continued to increase at higher flows and velocities largely remain suitable for shad until flows exceed 6,000 cfs.

Passage conditions for river herring (blueback herring and alewife), using 1.0 ft minimum depth criteria show almost continuous passage opportunities at 482 cfs with multiple continuous pathways becoming available at flows over 1,000 cfs. Because the herring velocity criteria is somewhat slower than for American shad, the model predicted more impassable area within the bedrock channels due to rapid currents. However, it appears likely that herring could ascend the channels along the bottom or along the margins at 482 cfs. Velocities within the bedrock habitat increase with increasing flows, with excessive velocities through the bedrock at flows over 4,000 cfs.

Atlantic Salmon Passage

Efforts to restore Atlantic salmon (*Salmo salar*) to the Merrimack River were abandoned in 2013 after consistently low return numbers were observed, but the species may still occasionally be present in the Project area. Efforts since 2013 have shifted towards the restoration of the remaining migratory fish species, notably river herring and shad (Cleantech Analytics 2017). Atlantic salmon counts are available for the Lawrence Project downstream (Table E.7-16).

In 1996, a radio telemetry study was performed to determine the extent to which the Lowell and Lawrence downstream fish bypass systems are used by radio-tagged Atlantic salmon smolts. The fish bypass systems at both the Lowell and Lawrence Hydroelectric Projects were not found to be effective at passing radio-tagged Atlantic salmon smolts, and at both sites, most of the downstream passage was through the turbines. At the Lowell Project, 13% of the radio-tagged salmon used the bypass, a significant increase compared to the 4% bypass usage by radio-tagged salmon in 1990. Only four (15%) of the radio-tagged salmon that passed the Lowell Project made it downstream to the Lawrence Project's headpond and of these, none were recorded passing the Lawrence site. Predation appears to have been a factor in the disappearance of some radio-tagged salmon released upstream of both hydroelectric sites (NAI 1996).

The effectiveness of the Lowell Project at safely passing downstream migrating Atlantic salmon smolts, as well as passage routing and turbine survival was evaluated in 2001. Using twenty radio-tagged salmon smolts to test three bypass flows, fish bypass efficiency at the Lowell Project averaged 32% and ranged from 15% passage with a bypass flow of approximately 2% of turbine flow to 42% passage with approximately 4% bypass flow. No turbine-passed fish appeared to be injured as a result of turbine passage. Similar to the 1996 study, predation in the tailrace and downstream of the Project seem to have a substantial impact on the survival rates of salmon smolts emigrating past the Lowell Project (Boott 2001).

E.7.3.1.5 Essential Fish Habitat

Based on a review of the NMFS online database, the Lowell Project reach of the Merrimack River is designated essential fish habitat (EFH) under the Magnuson-Stevens Fishery Conservation and Management Act for Atlantic salmon (National Oceanic and Atmospheric Administration [NOAA] undated). Essential fish habitat was defined as "all waters currently or historically accessible to Atlantic salmon within the streams, rivers, lakes, ponds, wetlands, and other water bodies of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut" (New England Fishery Management Council [NEFMC] 1998).

E.7.3.1.6 Benthic Macroinvertebrates

Benthic macroinvertebrates (BMI) are small aquatic animals and the aquatic larval stages of insects. They include dragonfly and stonefly larvae, snails, worms, and beetles. They lack a backbone, are visible without the aid of a microscope, and are found in and around water bodies during some period of their lives. Benthic macroinvertebrates are often found attached to rocks, vegetation, logs and sticks or burrowed into the bottom sand and sediments (USEPA undated). These organisms provide a link between a system's primary productivity and its aquatic consumers through the conversion of plant biomass to consumable energy. Benthic macroinvertebrates can be useful indicators of water quality because many species have a wide range of tolerances to pollution.

Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) (EPT) species are highly sensitive to pollution. Furthermore, EPT species are high-quality forage for a variety of freshwater fish species.

In recent years, the MADEP, NHDES, the Merrimack River Initiative (MRI), and numerous smaller watershed committees have begun conducting macroinvertebrate biomonitoring studies in the Merrimack River basin (USACE 2003). According to the USACE (2003), benthic macroinvertebrate sampling was conducted at 44 locations throughout the Merrimack River Basin (10 mainstem and 34 tributary). Artificial substrates were deployed in August 1994 and collected seven weeks later after a colonization period. The results of the MRI study were published in November 1996 in a two-part study report titled Merrimack River Bi-State Water Quality Report, Part One and the Merrimack River Bi-State Biomonitoring Report, Part Two.

As shown above in Table E.7-13, the Instream Flow Habitat Assessment and Zone of Passage Study identified that benthic macroinvertebrates showed the highest estimates of WUA of all species groups, with a maximum of 24,062 m^2 at 2,000 cfs, and maintained high habitat values (>10,000 m^2) from 500 cfs to 10,000 cfs. The 2D model predicted suitable habitat for BMI throughout the Bypass Reach, although the highest quality habitat occurred in the upper end of the reach and near the bottom of the reach.

Three macroinvertebrate species of management concern that are entirely or semi-aquatic potentially reside in the Lowell Project vicinity of the Merrimack River. These species include the eastern pondmussel (*Ligumia nasuta*), the cobra clubtail (*Gomphus vastus*) and the umber shadowdragon (*Neurocordulia obsoleta*). These species were identified as species of special concern in Massachusetts (Commonwealth of Massachusetts 2018 *a*).

E.7.3.1.7 Aquatic Invasive Species

Invasive species are defined as non-indigenous plant or animal species that aggressively compete with native species. These species often out-compete local native species, impacting biodiversity, recreation, and human health. The Merrimack River supports a relatively large number of invasive species. The Invasive Plant Atlas of New England (IPANE), NHDES, and the MRWC identifies the species listed in Table E.7-22 as potentially occurring in the general vicinity of the Project. Those species that were observed during field studies performed at the Project are indicated with an asterisk (*).

Table E.7-22. Aquatic Invasive Species Likely to Occur in the Project Vicinity

Common Name	Scientific Name
Common reed*	*Phragmites australis*
Curly-leaved pondweed	*Potamogeton crispus*
Eurasian water milfoil	*Myriophyllum spicatum*
Carolina fanwort	*Cabomba caroliniana*
Purple loosestrife*	*Lythrum salicaria*

Common Name	Scientific Name
Twoleaf milfoil	*Myriophyllum heterophyllum*
European water chestnut	*Trapa natans*
Yellow Iris	*Iris pseudacorus*
European water-clover	*Marsilea quadrifolia*
Watercress	*Nasturtium officinale*
Reed canarygrass	*Phalaris arundinacea*
Yellow iris	*Iris pseudacorus*
Flowering rush	*Butomus umbellatus*
Yellow floating heart	*Nymphoides peltata*
Asian clam	*Corbicula fluminea*

Sources: MRWC 2015; IPANE 2018

E.7.3.2 Environmental Analysis

FERC's SD2 identified effects of continued Project operations on fish and aquatic resources as potential resource issues. Specifically, SD2 identified the following needed to be analyzed for site-specific effects:

- Effects of continued project operation on resident and migratory fisheries resources in the impoundment, canal system, bypassed reach, and Merrimack River.
- Effects of continued project operation on the aquatic macroinvertebrate community in the impoundment, canal system, bypassed reach, and Merrimack River.
- Effects of continued project operation on fish passage for migratory species, including American shad, river herring, and American eel.

The following potential resource issues related to fish and aquatic resources were identified to be analyzed for both cumulative and site-specific effects:

- Effects of continued project operation on migratory fisheries resources in the impoundment, canal system, bypassed reach, and Merrimack River.

E.7.3.2.1 Site-Specific Effects

Effects of Continued Project Operation on Fish Passage for Resident and Migratory Species

The Merrimack River is home to a diverse assemblage of fishes. Stolte (1982; as cited in the Merrimack River Technical Committee for Anadromous Fishery Management of the Merrimack River Basin, 1997) noted that during the last 150 years, over 15 non-indigenous species such as largemouth bass, smallmouth bass, walleye, common carp, rainbow trout, brown trout, various catfish species and goldfish have established through human introductions within the Merrimack River. At that time, the Merrimack River was identified as home to approximately 50 species of fish, nine of which were anadromous. The slower moving, ponded reaches of the Merrimack contain a higher predominance of warm-water species whereas those areas with higher gradient contain the majority of cold-water species. Hartel et al. (2002) identified a total of 57 reproducing fish species within the drainage; 21 primary species (i.e., those living full life cycle in freshwater), 8 secondary species (i.e., those with physiological capacity to move between fresh and salt water), 18 introduced species, and 10 diadromous species.

Fish assemblage sampling within the Lowell impoundment and bypass reach during the spring, summer and fall of 2019 resulted in the identification of 24 fish species. Of those species, 21 are considered freshwater and 3 are considered diadromous. The species collected during the 2019 sampling resulted in a similar and expected fish assemblage in the Project vicinity compared to existing information on the Merrimack River fish community (Hartel et al. 2002). Based on the results of the 2019 Fish Assemblage Study, approximately 75% of the composition of fish species in the impoundment and bypassed reach was comprised of five or less species in all sampling seasons (NAI 2021d). As expected, there is a slight seasonal shift in the fish community in both the impoundment and bypass reach. Table E.7-23 presents the most abundant fish species in the impoundment for each season and Table E.7-24 presents the most abundant fish species in the bypass reach for each season. Additionally, fish assemblage was found to differ based on habitat, as described in Section E.7.3.1.

Table E.7-23. Top five most abundant fish species each season in the impoundment from the 2019 Fish Assemblage Study.

Spring		Summer		Fall	
Species	**Percent Composition**	**Species**	**Percent Composition**	**Species**	**Percent Composition**
Redbreast Sunfish	23.7	Redbreasted Sunfish	27.1	Spottail Shiner	33.9
Smallmouth Bass	21.9	Pumpkinseed	17.5	Alewife	16.8
Spottail Shiner	27.6	Spottail Shiner	10.9	Fallfish	13.7
Fallfish	5.9	Bluegill	10.7	Smallmouth Bass	9.2
Bluegill and White Sucker[1]	8.2	Smallmouth Bass	6.9	Redbreasted Sunfish	8.2
Total	**87.3%**	**Total**	**73.1%**	**Total**	**81.8%**

Note: 1 Bluegill and white sucker had the same percent composition (4.1%).

Table E.7-24. Most abundant fish species each season in the bypass reach from the 2019 Fish Assemblage Study.

Spring		Summer		Fall	
Species	Percent Composition	Species	Percent Composition	Species	Percent Composition
Spottail Shiner	48.8	Fallfish	55	Smallmouth Bass	64.2
Fallfish	27.5	Spottail Shiner	14.4	Margined Madtom	13.2
American Eel	12.5	Smallmouth Bass	10.9	Redbreast Sunfish	6.6
Bluegill	2.5	White Sucker	8.8	Tessellated Darter	3.8
Smallmouth Bass	2.5	American Eel	5.3	White Sucker	2.8
Total	**93.8%**	**Total**	**94.4%**	**Total**	**90.6%**

Overview of Migratory Species and Fish Passage

Existing information for the Project, along with the results of the studies completed by the Licensee in 2019 and 2020, demonstrate that existing operations under the terms of the current license and the Project's CFPP are maintaining and supporting resident game and non-game fish species, as well as migrating anadromous fish, and habitat for aquatic species in the Merrimack River upstream and downstream of the dam.

The CFPP includes details of operational measures undertaken by Boott to protect upstream and downstream migrating anadromous fish. The CFPP is based on several fisheries studies conducted at the Project and experience gained at the Project since the installation of the Project's fish lift and fish bypass facilities. The priority species for management at the Lowell Project are the catadromous American eel and three anadromous Alosidae species (American shad, blueback herring, and alewife). Atlantic salmon restoration is no longer a management focus for the Merrimack River. Because of minimal fluctuation of the impoundment and adherence to a strict minimum flow regime, the operation of the Project has little effect on overall river flow in the lower Merrimack River.

The licensee has consulted with the USFWS, New Hampshire Fish and Game Department (NHFGD), MADFW, and NMFS extensively regarding fish passage at the Project. Boott provides a post-season update on the fish passage at the Lawrence and Lowell Hydroelectric Projects annually and the agencies have the opportunity to recommend improvements to the fish passage facilities. The fish passage facilities at both Projects are continually monitored and modified to increase effectiveness at the agencies' requests and recommendations (Cleantech Analytics 2017).

The recent construction of the pneumatic crest gate was strongly endorsed by the Federal and state (both New Hampshire and Massachusetts) fishery agencies due to its anticipated benefits to migratory species. The USFWS, NMFS, MADFW, and NHFGD submitted letters of support to the Commission for the pneumatic crest gate system. The system allows rapid re-inflation following periods of high flow, which prevents delay in upstream fish passage which occurs with lost or damaged wooden flashboards. The pneumatic crest gate system is expected to maintain consistent water levels, reduce leakage from the dam, and minimize the need for impoundment drawdowns, which all provide improved fish passage and spawning habitat. The reduction in leakage is expected to improve upstream passage efficiency by decreasing false attraction flow at the dam (FERC 2011).

American Eel Passage

The impoundment and river segment in the vicinity of the Project would be suitable for foraging, growth, and development of American eel prior to their downstream spawning migrations. American eels are adaptable and can utilize a wide range of riverine, lake, or reservoir habitat (McCleave 2001, Greene et al. 2009). The passage of American eel upstream of hydropower dams can expose the eventual out-migrating silver eels to migratory delay at each dam and mortality when passing through turbines or over spillways.

A radio-telemetry assessment of the downstream passage success for adult silver-phase American eels was performed during the fall of 2019 (NAI 2021a). Monitoring of outmigrating adult American eels focused on the evaluation of movement through the Project impoundment, residence time immediately upstream of the Pawtucket Dam and prior to passage, passage route utilization and estimation of downstream passage survival at the Project. During the 2019 American Eel Passage Assessment, the majority of American eels (92.5%) passed downstream of Lowell via the E.L. Field turbine units, while two eels used the downstream bypass and four eels used the bypassed reach (NAI 2021a). The limited use of the downstream bypass system at E.L. Field is similar to the results of the 2018 downstream eel passage evaluation.

Downstream passage survival was estimated for all radio-tagged eels from the point of initial detection upstream of the Pawtucket Dam downstream to Lawrence. This resulted in an estimated downstream passage survival for silver-phase American eel at Lowell of 75.5% (75% CI = 71.4%-79.6%). This estimate of downstream passage survival for adult eels at the Project includes any background (i.e., natural) or tagging-related mortality for the species in the reach from approach to the Pawtucket Dam to Lawrence. As a result, this estimate should be viewed as a minimum estimate of total Project survival (i.e., due solely to Project effects) for adult eels at the Project. Due to the limited distribution of downstream passage route selection, route-specific estimates of passage were developed for only individuals using turbine units at the E.L. Field Powerhouse (n = 136; 75.0% survival; 75% CI = 70.6%-79.4%). The limited number of radio-tagged eels passing the Project via spill or the downstream bypass system were all determined to have successfully approached the Lawrence Project following downstream passage at Lowell (NAI 2021a).

A TBSA model was conducted as part of the Fish Passage Survival Study (NAI 2021f) for American eel. The estimated range of survival for eels passing downstream through the E.L. Field turbines ranged from 71-39%, with the predicted rate of survival for adult eels decreasing as body size/length increased. In the case of adult eels, the TBSA model tended to underestimate turbine survival when compared to the empirical results from the Downstream American Eel Passage Assessment.

American shad and river herring passage

The presence of herring in the Merrimack River appears to be strong in recent years. In 2016, record numbers of herring (since the establishment of the restoration efforts,) were observed at the Amoskeag Dam, upstream of the Lowell project. The returns have been so successful that the large number of herring ascending the fish ladder at the Amoskeag Dam overwhelmed the trap and truck operation in 2016 (Cleantech Analytics 2017). In 2018, the Lawrence facility passed river herring upstream in the highest number (418,689) since the project was built over 30 years ago, and the Lowell project passed about 58% of those fish upstream, through its fish lift (62,421) and fish ladder (182,268) (Enel 2018). In 2016, 70% of the herring that passed at Lawrence also passed at Lowell (Enel 2016). Also, in 2018, while only 26,347 American shad were passed upstream at Lawrence, 56% of those were passed through the Lowell project, through its lift (4,630) and ladder (10,171). The high ratio of passage success for shad from Lawrence through Lowell is the highest ever observed in over 30 years of passage comparison (Enel 2018).

During the 2019 Juvenile Alosine Downstream Passage Assessment, 83% of juvenile alosines eventually passed downstream via the turbine units. Use of the existing downstream bypass system was estimated at 17% (NAI 2021b). During the 2019 Adult Alosine Downstream Passage Assessment, the majority of adult alewives passed downstream of Lowell via the E.L. Field turbine units (52% of radio-tagged alewives) or utilized the downstream bypass (45% of radio-tagged alewives). During 2020, the overall effectiveness of the E.L. Field fish lift for adult alewife passage was estimated at 43.9%, while the overall effectiveness of the Pawtucket Dam fish ladder for adult alewife passage was estimated at 75.6%. Also, during 2020, the overall effectiveness of the E.L. Field fish lift for adult American shad passage during 2020 was estimated at 30.4%, while only two tagged shad utilized the fish ladder (NAI 2021c).

The Fish Passage Survival Study (NAI 2021f) used the TBSA desktop tool to estimate total project survival for juvenile alosines at the Project. Estimates of turbine passage were inversely related to body length for each species/life stage considered with highest survival estimated for small juvenile shad or herring at two inches of length (~99%), and total project survival at Lowell for juvenile alosine-sized fish is estimated at 94.8%. Passage failures were attributed to fish passing downstream via the turbines (2.1% of total losses) and the downstream bypass facility/spill (3.1% of total losses).

The TBSA analysis conducted for adult alosines as part of the Fish Passage Survival Study produced a range of survival estimates for turbine survival through the Project's E.L. Field powerhouse Kaplan units. Within that range of estimates, the probability of mortality due to blade strike increased as body size increased. In the case of adult alosines, the TBSA model tended to overestimate turbine survival.

Effects of continued project operation on the aquatic macroinvertebrate community in the impoundment, canal system, bypassed reach, and Merrimack River

There is limited information available regarding aquatic macroinvertebrates at the Lowell Project. The pneumatic crest gate will reduce impoundment fluctuations and will therefore help to protect benthic macroinvertebrate communities within the littoral zone of the Project impoundment. Boott proposes to continue to operate the Project in ROR mode, for the purpose of protection of fish, aquatic habitat, and wildlife resources.

Hydroelectric projects have been shown to influence benthic macroinvertebrate communities by altering flow conditions and thereby habitat, water quality, and instream transport processes. The severity of impact on aquatic resources is largely influenced by the extent of flow regulation. The Project operates as a ROR facility, which uses the natural flow of the water to produce electricity. As such, flow regulation is minimal at ROR projects, which are often considered low impact facilities compared to peaking and storage hydroelectric projects. Although hydropower operations may affect the macroinvertebrate communities to some degree, the Licensee anticipates that the continued ROR operation of the Project will not affect macroinvertebrate communities.

E.7.3.2.2 Cumulative Effects

In SD2, the Commission identified that migratory fish resources could be cumulatively affected by the continued operation of the Project in combination with other hydroelectric Projects on the river. The geographic scope for the cumulative effects analysis on migratory fish is the Pemigewasset River from the Eastman Falls Dam and the Winnipesaukee River from the Lakeport Dam, to the confluence of the Winnipesaukee and Pemigewasset Rivers (which form the Merrimack River), and the Merrimack River downstream to the Atlantic Ocean.

Boott believes that the continued operation of the Project, as proposed, will limit cumulative effects on the aquatic habitat, and resident and migratory fisheries resources in the impoundment, canal system, bypass reach, and Merrimack River based on the proposed minimum flow, operating the Project to maintain water quality standards, operating the pneumatic crest gate per the operation plan approved by FERC on March 30, 2015, operating fish passage facilities consistent with the CFPP approved by FERC on November 28, 2000.

The current operation of the Project has been designed to consider and support ongoing efforts to maintain resident and migratory fisheries to the Merrimack River Basin. The Project is operated in a ROR mode, consistent with minimum flow requirements, in order to comprehensively address river flows and related hydroelectric project operations to best support aquatic life downstream of the Project, including migratory fish species. Boott has undertaken substantial enhancements in the form of upstream and downstream passage measures at the Project, which should continue to minimize any cumulative effects to fisheries resources in the Merrimack River resulting from operation of the Project.

Similarly, Boott has undertaken a number of studies relative to fish restoration efforts at the Project that are designed to assess not only direct Project effects on fishery resources, but also to examine the potential cumulative effects of the Project on the overall migratory fish restoration efforts.

Operation of the Project may cumulatively affect migratory fish species including American eel, American shad, river herring (alewife and blueback herring). Upstream and downstream fish passage facilities including a fish elevator and downstream fish bypass at the E.L. Field Powerhouse, and a vertical-slot fish ladder at the Pawtucket dam are currently in place at the Project. To date, there has been no significant mortality observed or documented at the Project. Any mortality that may occur from entrainment or impingement of fish species at the Project would contribute to the cumulative effect of the fisheries in the Merrimack River.

Notably, in its 2007 finding on the petition to list the American eel, the USFWS found that:

- The species is highly resilient.
- The reproductive contribution of eels from coastal and estuarine habitat is substantial, and habitat in the lower reaches of a watershed produces more eels than habitat higher in the watershed.
- Loss of habitat resulting from dams does not threaten the long-term persistence of the American eel.
- American eel are able to navigate many barriers.
- Turbines can affect the regional abundance of eel, but no evidence indicates that turbines are affecting the species at the population level (USFWS 2007).

Removing the four mill powerhouses from the Project will result in much lower flows being routed through the downtown canal system, largely eliminating the possibility that outmigrating diadromous fish would be attracted into the canal system, and fully eliminating the possibility of entrainment in the downtown units.

E.7.3.2.3 Proposed Environmental Measures

Boott proposes continued operation of the Project with certain environmental PM&E measures consistent with the measures required by the Project's existing license. Boott believes that the continued operation of the Project, as proposed, will limit effects on fish and aquatic resources. Specifically:

- Boott proposes to operate the Project in a ROR mode using automatic pond level control of the E.L. Field powerhouse units, to protect fish and wildlife resources downstream from the Project. ROR operation may be temporarily modified for short periods to allow flow management for other project and non-project needs, e.g., downtown canal water level management, raising the crest gates following a high-water event, or for recreational purposes.

- During the upstream fish passage season, which generally runs from late April through mid-July, Boott proposes to release a minimum flow of 500 cfs into the bypass reach via the existing fish ladder at the Pawtucket Dam. The operating period for the fish ladder will continue to be determined annually through consultation with the MRTC, consistent with current practice. At all other times, Boott proposes to release a minimum flow of 100 cfs or inflow, whichever is less, to the bypass reach downstream of the Pawtucket Dam, for the protection of aquatic habitat within the bypass reach.

- Boott proposes continued adherence to the requirements of the Project's existing Crest Gate Operation Plan (approved by FERC on March 30, 2015). Maintaining stable water upstream levels will protect and enhance fish and wildlife habitat in the Project impoundment.
- Boott proposes to replace the existing fish lift with a short fish ladder to pass migratory fish from the E.L. Field powerhouse tailrace to the bypass reach, such that all fish would be passed upstream of the Project via the existing fish ladder at the Pawtucket Dam. The Licensee will consult with the MRTC member agencies to determine the design and installation schedule for the proposed ladder.
- Following installation and operation of the fish ladder at the tailrace, Boott proposes to cease operations of the upstream fish elevator at the tailrace. The timing of cessation of the upstream fish elevator will be determined based on consultation with the MRTC.
- Boott proposes to continue to work with the MRTC to identify any necessary minor modifications to the existing upstream fish ladder located at the Pawtucket Dam, and/or to the existing weirs in the bypass reach to improve passage.
- Boott proposes the installation of new trashracks or other fish exclusion facility at the E.L. Field Powerhouse which will be consistent with current USFWS passage guidelines , to prevent entrainment of fish through the turbines. Downstream passage of fish will continue to be provided via the existing sluice gate in the left forebay wall of the E.L. Field Powerhouse. The Licensee will consult with the MRTC member agencies to determine the design and installation schedule for the proposed fish exclusion system. Boott reserves the right to seasonally deploy the new trashracks or other exclusion facility only during the downstream fish passage season (mid-May – November), and to use the existing trashracks outside of the fish migration season.
- Boott proposes to develop a Fishways Operation and Management Plan in consultation with the MRTC. The proposed plan would effectively replace the Project's existing Comprehensive Fish Passage Plan.
- Boott proposes to remove the four mill power stations and associated canal infrastructure from the new FERC license. Ceasing the operation of the mill power station units will eliminate the possibility of outmigrating diadromous fish being entrained through those units.

Boott notes that certain studies required by the Commission are ongoing, including the Three-Dimensional CFD Modeling Study. Boott will consult with stakeholders regarding the results and recommendations of these studies and potential PM&E measures. As appropriate, Boott may propose additional PM&E measures in a supplement to this license application.

E.7.3.3 Unavoidable Adverse Impacts

Unavoidable adverse impacts are those effects that may still occur after implementation of PM&E measures. Operation of the Project may continue to result in the delay or entrainment of American eels, American shad, river herring, Atlantic salmon, striped bass, sea lamprey, and other resident species, but these effects are expected to be limited in scope and will not have an effect at the population level.

E.7.4 Terrestrial Resources

The subsections below describe terrestrial resources in the vicinity of the Project and consider the effects of continued operation of the Project as proposed by the Licensee on these resources. Descriptions of the affected environment, the environmental analysis, the proposed environmental measures, and the identification of unavoidable adverse effects were developed based on available data presented in the Licensee's PAD, other existing information, and from the results of the Recreation and Aesthetics Study performed by Boott (HDR 2021a), included in Appendix B of this exhibit.

E.7.4.1 Affected Environment

The Merrimack River watershed encompasses approximately 5,010 square miles within the states of New Hampshire and Massachusetts. It is the fourth largest watershed in New England. Although the Merrimack River watershed is heavily forested (75 percent of the land area is covered with forest), it also supports all or parts of approximately 200 communities with a total population of 2.6 million people (USEPA 2020b; USACE 2006).

Ecoregions are used to provide general understandings of vegetation, wetland, and terrestrial habitat in an area (USEPA 1997). The Merrimack River watershed is located in both the Northeastern Highlands ecoregion and the Northeastern Coastal Zone. The north and westerly portions of the watershed, located in the Northeastern Highlands, are characterized by low mountains and mostly ungrazed forest and woodland. The southern portion of the watershed is located in the Northeastern Coastal Zone, which is characterized primarily as modified woodland and forest. However, the states of New Hampshire and Massachusetts report that undeveloped open space along the Merrimack River watershed generally decreases further downstream as riverfront communities are more industrialized (MEOEEA 2001; NHDNCR 2018).

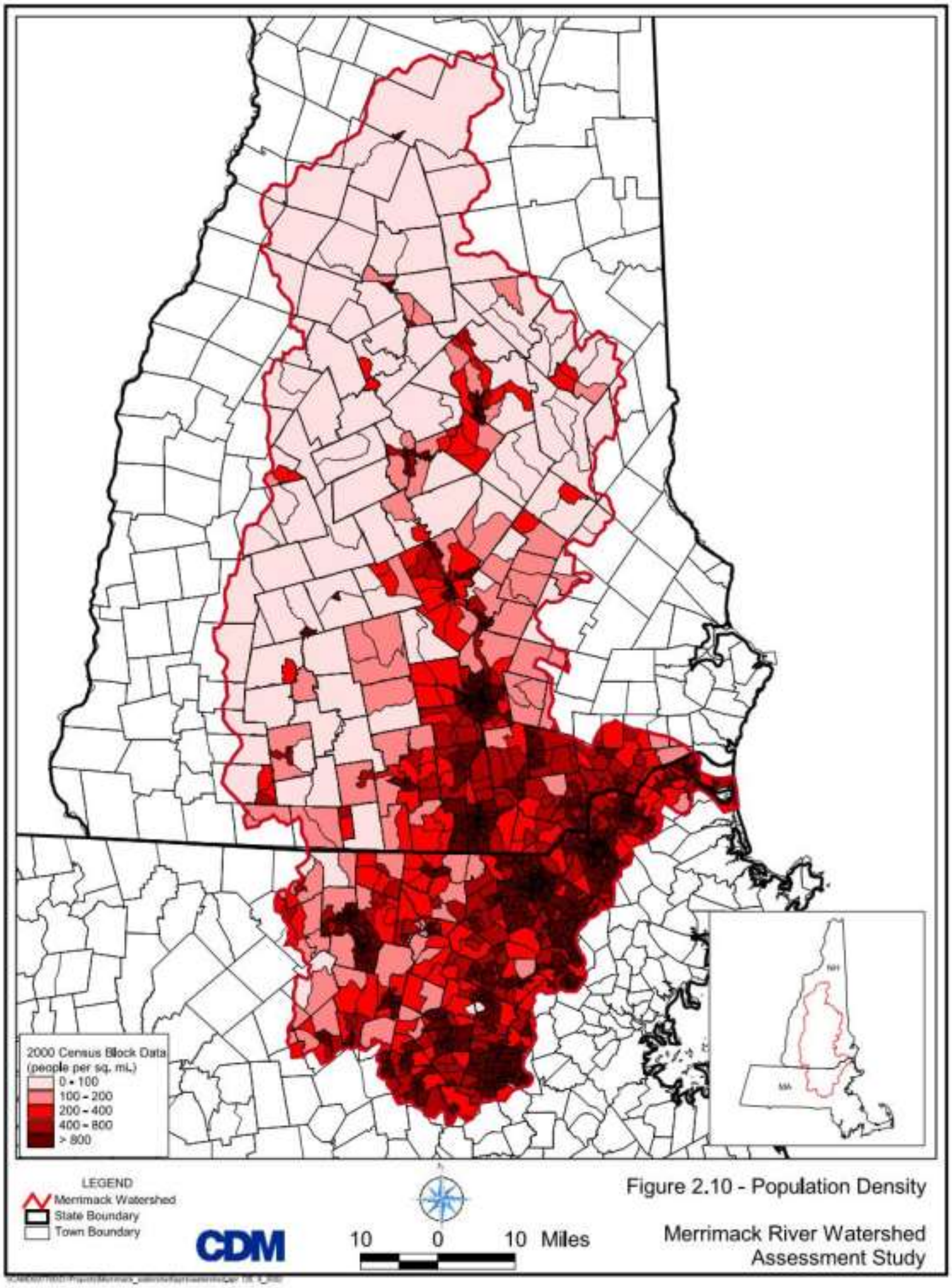
Along the upper northern boundary of the Merrimack River watershed, the relatively undeveloped White Mountain National Forest in New Hampshire provides almost 800,000 acres of protected land; this region also provides over one million acres of private forest and agricultural land (NHDNCR 2018). The Project dam is located at RM 41 on the Merrimack River, and the impoundment extends upstream approximately 23 miles almost to the City of Manchester in New Hampshire. The Project impoundment is characterized by the urban/industrialized cities of Nashua, New Hampshire and Lowell, Massachusetts. In the vicinity of the Project in Lowell, Massachusetts, the Merrimack River flows through a region of rapid population growth and development stemming from the 1800s that is still heavily influenced by the growing Boston urban metropolitan area (Figure E.7-21).

The area near the Project's dam and E. L. Field powerhouse is urban in nature and the vegetation found within the project area is typical of an urbanized setting in this region. The project area has sparsely vegetated shorelines and a narrow riparian corridor consisting of grasses, weeds, and scattered wild shrubs. Early successional/young forest/shrub lands cover types occur in scattered patches along the shoreline of the river intermixed with small stands of mature forest and disturbed sites (fill slopes and millwork areas adjacent to developed sites) (FERC 2011). The developed lands nearby include the University of Massachusetts - Lowell, a variety of housing and residential subdivisions and an extensive network of roads and highways. The area south of these primary power-generating facilities includes several industrial sites, and the bisecting 5.5-mile downtown canal system.

The Merrimack River watershed's land use composition, from the relatively undeveloped White Mountain National Forest in northern New Hampshire to highly urbanized areas along the mainstem of the Merrimack River, is reflected in the basin's general land use and terrestrial resources (Figure E.7-22).

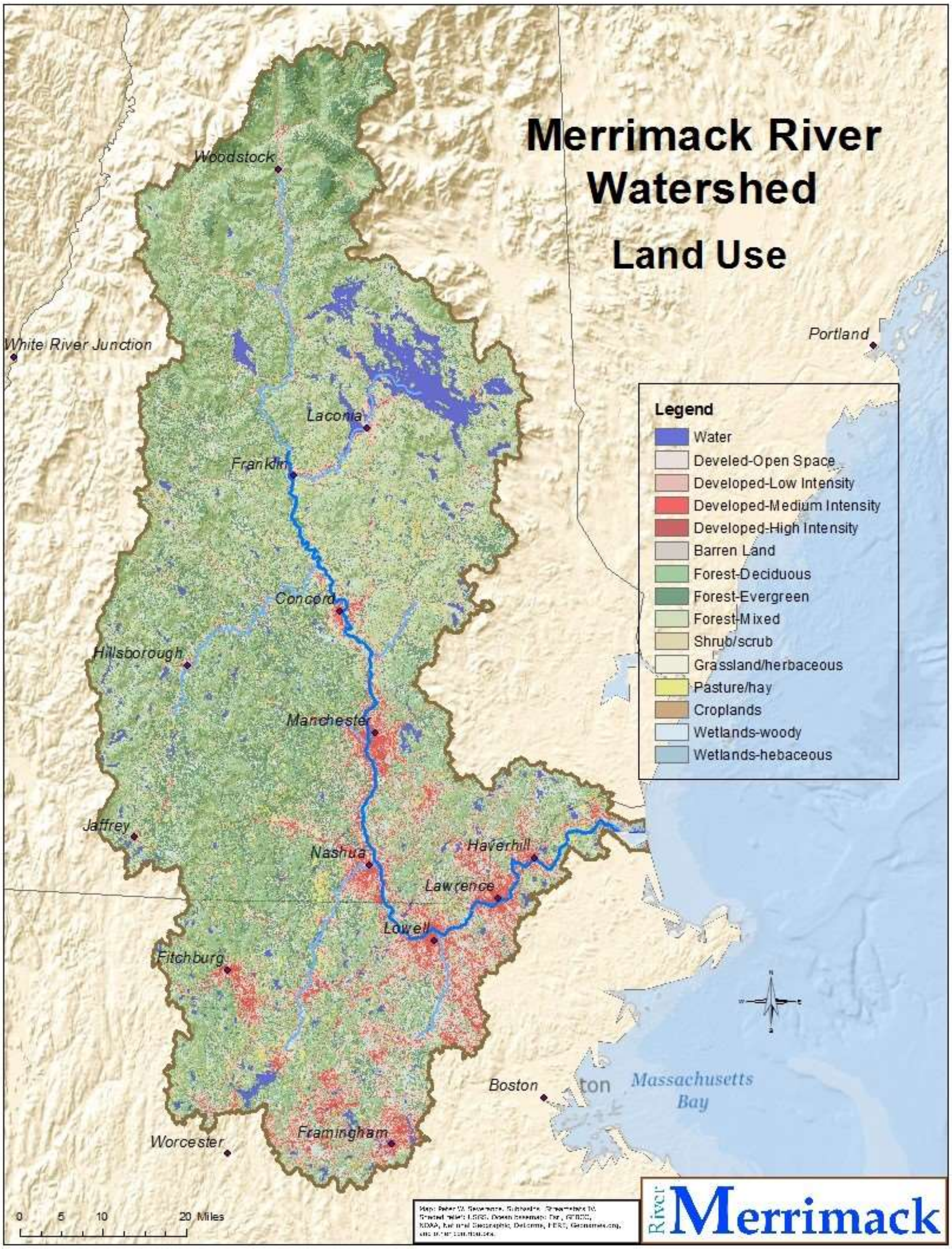
For purposes of describing the existing condition of terrestrial wildlife and botanical resources, this discussion has been divided into the following subsections: (1) botanical resources, (2) wetland, riparian, and littoral habitat, and (3) wildlife. As appropriate, these subsections describe other germane studies conducted by Boott relative to their resource areas.

Figure E.7-21. Population Density in the Merrimack River Basin



Source: USACE 2002

Figure E.7-22. Land Use in the Merrimack River Basin



Source: Merrimack River Watershed 2018.

E.7.4.1.1 Recreation and Aesthetics Study

In accordance with the Commission's SPD, Boott conducted a Recreation and Aesthetics Study to determine the adequacy and capacity of existing recreational facilities, assess potential effects of water levels and flow rates on existing recreational facilities, other forms of recreational assessments, and identify areas within the canal system where vegetation growth on historic canal walls are a concern. Methods and results of the Recreation and Aesthetics Study are described in detail in Boott's Recreation and Aesthetics Study report (HDR 2021a) which was filed with the Commission on February 25, 2021. A portion of the results of this study were used to help form the baseline characterization of terrestrial habitat and wildlife within the Project area; as such the study methods are summarized in this section, with the relevant results discussed in the subsections below.

Boott conducted a Recreation and Aesthetics Study, in part, to identify areas within the canal system where vegetation growth on historic canal walls are a concern, including background literature reviews, desktop analyses, and field investigations.

The visual survey for vegetation growth was conducted between September 25 and 27, 2019. The survey was conducted to identify vegetation growth along the canal walls within the study area. Technicians identified the relative quantity and spatial distribution of each vegetation type using aerial photography and observations of habitat and specific plant species occurrences. Terrestrial vegetation types occurring in the study area were described based on a review of existing information, an inspection of aerial photography, a review of the USGS 7.5-minute quadrangles, and observations of habitat and specific vegetation type occurrences during the field surveys.

For the purposes of examining vegetation type distribution, the study area was divided into the six canals associated with the Lowell Project canal system including: 1) Pawtucket Canal, 2) Northern Canal, 3) Western Canal, 4) Merrimack Canal, 5) Eastern Canal, and 6) Hamilton Canal.

Visual qualitative surveys were conducted in the study area by foot along the shorelines of the canals, or via an NPS boat for the surveys conducted in the Pawtucket Canal from the Swamp Locks and Dam to the Merrimack River. Vegetation was characterized by dominant type (i.e., Herbaceous, Scrub-Shrub, Trees, Forested, or Mixed). The vegetation type assessments were based on overall dominant vegetation characteristics at the time of the survey that may have variations within small areas. In addition, the shoreline/canal was characterized by dominant features (i.e., Block Wall, Concrete, Earthen/Terrestrial Cultural, Stone Wall, Block Wall/Concrete/Stone Wall Mix).

Mapped Vegetation Polygons and Vegetation Points (VPs)[19] were located using an EOS Positioning Systems Arrow 100™ GNSS receiver linked to an iPad™ Air 2 or Android device operating Collector for ArcGIS™ hand-held Global Positioning System (GPS) unit (equipped with a data dictionary aiding in feature attribution). The presence and extent of cover of the vegetation on/along the canal walls observed at the time of the field survey

[19] Vegetation points were used to identify areas along canal walls where a single vegetation type point was recorded. Vegetation points generally identify where a single species (e.g., shrub, tree) was located.

was evaluated based on photographs and field observations. Geospatial vegetation data were transferred to a Geographic Information System (GIS) format and used to develop both visual maps depicting vegetation presence boundaries and VPs along the canal walls as well as tabular information quantifying the abundance and distribution of dominant vegetation types in the study area. Vegetation polygons were then analyzed to calculate the percentage represented by each vegetation category within each canal; VPs were not included in vegetation category percentage calculations because they represent a single point on the canal wall.

Relevant study results are discussed in the subsections below. As noted above, these subsections also describe other germane studies conducted by Boott relative to their resource areas.

E.7.4.1.2 Botanical Resources[20]

As presented in Section E.7.1, the Project is located in both the Northeastern Highlands ecoregion and the Northeastern Coastal Zone. The north and westerly portions of the watershed, located in the Northeastern Highlands, are characterized by low mountains and mostly ungrazed forest and woodland. The southern portion of the watershed is located in the Northeastern Coastal Zone, which is characterized primarily as modified woodland and forest. The Project is also located in the New England Physiographic Province. The Taconic, Green, and White Mountain ranges are distinct features of the New England Physiographic Province. The Taconic Mountains are a north-south trending mountain range along the western edge of the province and are thought to be formed by erosion of an upper block of a large thrust fault. Also, north-south trending, the Green Mountains exist primarily in Vermont and are made of Precambrian gneisses. The White Mountains are an exhumed mass of Paleozoic granite and include Mt Washington in New Hampshire, the tallest mountain in the region at 6,288 feet (NPS undated *a*).

The Lowell Project is located in the Seaboard Lowlands Section of the New England Physiographic Province. The Seaboard Lowlands Section is lower in elevation and less hilly than the adjacent New England Upland Section. Fenneman considered the Seaboard Lowlands Section as the sloping margin of the uplands, although it also roughly coincides with the area inundated by the ocean and areas of large proglacial lakes during the last glacial retreat (Stone and Borns 1986 as cited in Flanagan et al. 1999). In the vicinity of the Project, the Merrimack River flows through a region of rapid population growth and development that is heavily influenced by the Lowell metropolitan area. The local relief in the Merrimack River Valley in the Project vicinity is generally characterized as low, open hills.

Botanical resources in the Merrimack River corridor vary between urban areas and nonurban areas. In the vicinity of the Lowell Project, botanical resources are dominated by hemlock-hardwood-pine, Appalachian oak-pine, and grasslands (NHDFG 2015). These habitat types are discussed below in further detail.

[20] State-listed RTE plant species are discussed in Section E.7.5 of this Exhibit.

Hemlock-Hardwood-Pine Forest

Hemlock-hardwood-pine forest is a wide-spread habitat in the lower Merrimack River corridor. It is a transitional forest between Appalachian oak-pine and northern hardwood found at elevations less than 400 feet and greater than 1,500 feet, respectively. White pine (*Pinus strobus*) and eastern hemlock (*Tsuga canadensis*) are the dominant trees, but American beech (*Fagus grandifolia*) and patches of sugar maple (*Acer saccharum*), white ash (*Fraxinus americana*), and red oak (*Quercus rubra*) contribute to a variable species mix of this forest type. The understory contains small trees and shrubs such as witch hazel (*Hamamelis virginiana*), maple-leaved viburnum (*Viburnum acerifolium*), black birch (*Betula nigra*), black cherry (*Prunus serotina*), and ironwood (*Ostrya virginiana*). Typical plants found on the forest floor include starflower (*Trientalis borealis*), Canada mayflower (*Maianthemum canadensis*), and wild sarsaparilla (*Aralia nudicaulis*).

Most white pine stands that have grown up from abandoned pastures are examples of this type of hemlock-hardwood pine forest habitat. On fertile soils, white pine is replaced by hemlock or hardwoods over time. Older forests that have succeeded to later stages contain patches of larger diameter trees (>18 inches) hemlock or beech in the canopy, layers of young trees and shrubs in the understory, many standing dead trees, and abundant decaying wood on the forest floor. Large-sized cavity trees, pockets of wetlands, patches of acorn-rich oaks, seeps, and tall pine trees make some patches of this forest type especially rich for wildlife (NHDFG 2015; Swain 2020).

Appalachian Oak-Pine Forest

Appalachian oak-pine forests, with their abundance of nut-bearing oaks such as red oak, white oak (*Quercus alba*), and black oak (*Q. velutina*), and hickories such as shagbark (*Carya ovata*), pignut (*C. glabra*), and sweet pignut (*C. ovalis*), provide a rich food source for wildlife such as ruffed grouse (*Bonasa umbellus*), turkey (*Meleagris gallopavo*), gray squirrels (*Sciurus carolinensis*), and eastern chipmunks (*Tamias striatus*). Common understory shrubs and smaller trees of this forest type include black birch (*Betula lenta*), bigtooth aspen (*Populus grandidentata*), sassafras (*Sassafras albidum*), and yellow birch (*Betula alleghaniensis*). Blueberries (*Vaccinium angustifolium* and *V. pallidum*), black huckleberry (*Gaylussacia baccata*), sheep laurel (*Kalmia angustifolia*), and Pennsylvania sedge (*Carex pennsylvanica*), are typical understory plants. Raptors such as northern goshawk (*Accipiter gentilis*) feed on small mammals and find nesting and perching sites in white pines in the tree canopy. White pines adjacent to the Merrimack River provide key nest and perch sites for bald eagles (*Haliaeetus leucocephalus*), great blue herons (*Ardea herodias*), and osprey (*Pandion haliaetus*) (NHDFG 2015).

Many stands of Appalachian oak-pine forest are of the same age, approximately 80-100 years. They grew after farms were abandoned throughout the last century. Many wildlife species found in this forest type are attracted to patches of old or young trees within the larger forested landscape. Historically, the dry soils and warm temperatures in this region allowed occasional low-intensity fires to burn in these forests. Without fire, these forests have a higher proportion of white pine, hemlock, sugar maple and birch species (*Betula* spp.), than nut-bearing trees. Mature Appalachian oak-pine forests may also be denser due to a lack of low ground fires to maintain an open understory (NHDFG 2015).

Grasslands

The most common grassland habitats in the lower Merrimack River corridor are agricultural fields such as hayfields, pastures, and fallow fields. Grassland vegetation is a mixture of grass species, or a combination of grasses, sedges, and wildflowers. Most plants found in grasslands are non-native grasses, introduced for agricultural use. These include timothy (*Phleum pretense*), Kentucky bluegrass (*Poa pratensis*), orchard grass (*Dactylis glomerata*), and perennial ryegrass (*Lolium perenne*). Common native plants include big bluestem (*Andropogon gerardi*), little bluestem (*Schizachyrium scoparium*), and a variety of species of the wildflower genera including goldenrod species (*Solidago* spp.) and various Aster. Vegetation growing in grassland habitat ranges from less than 6 inches to over four feet in height. Vegetation height plays an important role in determining which wildlife species will use it. Few, if any, trees or shrubs are found in grasslands. Unless maintained, most grasslands will return to forest habitat (NHDFG 2015).

Major-River Floodplain Forest

The immediate shoreline of the Merrimack River and some portions of the canals within the Project area (e.g., the Pawtucket Canal near the confluence of the Merrimack River) include areas of floodplain forest and some of these areas have characteristics of Major-river Floodplain Forest as described by Swain (2020). Major-river floodplain forests are deciduous forested wetland communities, which develop next to rivers and streams and receive annual (or semi-annual) overbank flooding and alluvial silt deposition. Soils are predominantly sandy loams without soil mottles and without a surface organic layer. Flooding at these sites occurs annually and can be severe. An island variant of Major-river Floodplain Forests occurs on elevated sections of riverine islands and riverbanks of major rivers, where there are high levels of both natural and human disturbance. All floodplain forest communities in Massachusetts have silver maple (*Acer saccharinum*) as the defining tree, but associated plant species vary depending on the intensity and duration of the flooding and on geographic location. Common plant species occurring with silver maple include cottonwood (*Populus deltoides*), American elm (*Ulmus americana*), and/or slippery elm (*U. rubra*) in the subcanopy and shrubs are generally lacking. The herbaceous layer is usually dominated by a 3-6 ft. (1-2 m) tall, dense cover of wood-nettles (*Laportea canadensis*) and ostrich fern (*Matteuccia struthiopteris*) is sometimes abundant (Swain 2020). Other species growing along the upland margins include tree of heaven (*Ailanthus altissima*), staghorn sumac (*Rhus typhina*), the non-native bittersweet (*Celastrus orbiculatus*), riverbank grape (*Vitis riparia*), Virginia creeper (*Parthenocissus quinquefolia*), scattered Siberian elm (*Ulmus pumila*), purple loosestrife (*Lythrum salicaria*), poison ivy (*Toxicodendron radicans*), Boston ivy (*Parthenocissus tricuspidata*), mullein (*Verbascum thapsus*), and common ragweed (*Ambrosia artemisiifolia*) (HDR 2021a).

Ruderal Herbaceous/Scrub-Shrub/Forested

Ruderal Herbaceous/Scrub-Shrub/Forested areas in the Project vicinity are largely anthropogenic communities of herbaceous or mixed scrub-shrub and forested vegetation resulting from succession following complete or partial removal of native woody cover.

These communities are found in areas where the native forest vegetation has been cleared or partially cleared, in old fields, hedgerows, pedestrian walkways, along Project canals, roadways, etc. Characteristic species can include red maple, American elm, Siberian elm, bush honeysuckles (*Lonicera* spp.), tree of heaven, Boston ivy, poison ivy, goldenrods (*Solidago* spp.), and various grass species (HDR 2021a).

2019 Visual Survey for Vegetation Growth

In September 2019, a visual survey was conducted to identify vegetation growth along the canal walls within the Project area. A wide variety of vegetation types, occurrences, and distribution, ranging from herbaceous, non-woody plants to forested areas of trees and underbrush, and shoreline/canal types, ranging from earthen embankments to placed, uniformly sized blocks were observed during the study. In total, 96 Vegetation Polygons (representing 80% of the total survey data collected in the study area) and 24 VPs (representing 20% of the total survey data collected in the study area) were mapped between September 25 and September 27, 2019. As shown in Table E.7-25, the total study area encompassed approximately 44 acres and mapped vegetation on/along canal walls accounted for approximately 5 acres (11%) of the study area[21]. The Pawtucket Canal (19.63 acres; 44% of the total study area), Northern Canal (11.67 acres; 26% of the total study area), and Western Canal (5.51 acres; 13% of the total study area) represent more than 80 percent of the total study area (Table E.7-25).

At the time of the study, most mapped VPs within the total study area had a dominant vegetation type of Scrub-Shrub (46% of the total VP count), followed closely by Trees (38% of the total VP count). The majority of mapped Vegetation Polygons within the total study area had a dominant vegetation type of Mixed (41% of the total mapped vegetation area) at the time of the study. Mapped vegetation polygons with a dominant vegetation type of Forested were only recorded within the Western Canal (53% of the Western Canal study area), and the Northern Canal (28% of the Northern Canal study area) at the time of the study (HDR 2021a).

Maps showing the results of the vegetation assessment and mapping within the study area are illustrated in a 21-sheet, 11 by 17-inch vegetation type map set with numbered polygons (e.g., 1, 2) and VPs (e.g., VP1, VP2) for each vegetation polygon and/or VP, respectively in Appendix G of the Recreation and Aesthetics Study Report (HDR 2021a). Additionally, results from the canal wall vegetation mapping are compiled in Appendix H and field reconnaissance data is summarized in Appendix I of the Recreation and Aesthetics Study Report.

[21] VPs are not included in mapped vegetation acreage calculations because they represent a single point(s) on a canal wall.

Table E.7-25. Percent total acreage and mapped vegetation acreage of the six major canals associated with the Lowell Project Canal system

Canal	Area (acres)	Percentage (%) of Total Study Area	Mapped Vegetation Area (acres)	Percentage (%) of Total Study Area with Mapped Vegetation
Eastern Canal	4.03	9%	0.93	2%
Hamilton Canal	2.01	5%	0.35	1%
Merrimack Canal	1.40	3%	0.38	1%
Northern Canal	11.67	26%	0.89	2%
Pawtucket Canal	19.63	44%	1.33	3%
Western Canal	5.51	13%	0.90	2%
Total	**44.25**	**100%**	**4.78**	**11%**

Source: HDR 2021a

E.7.4.1.3 Invasive Plant Species

Invasive species are defined as non-indigenous plant or animal species that aggressively compete with native species. These species often out-compete local native species, impacting biodiversity, recreation, and human health. Invasive plants tend to appear on disturbed ground, and the most aggressive have the ability to invade existing ecosystems.

Non-native invasive species and noxious weeds are typically prolific pioneering species that have the ability to quickly outcompete native vegetation. These species grow rapidly, mature early, and effectively spread seeds that can survive for significant periods in the soil until site conditions are favorable for growth. Invasive plant species are prevalent throughout the Merrimack River Valley, as indicated by the IPANE (IPANE Undated), and have been observed along the banks of the Merrimack River, the Project's canals, and in some vegetation communities within the Project area. Of the 2,263 plant species in Massachusetts that have been documented as native or naturalized, about 725 (32%) are naturalized. Of these, the Massachusetts Invasive Plant Advisory Group (MIPAG) recognized 69 species as "Invasive," "Likely Invasive," or "Potentially Invasive" (Commonwealth of Massachusetts 2020). In accordance with the Invasive Species Act, HB 1258-FN, the New Hampshire Department of Agriculture, Markets & Food, Division of Plant Industry is the lead state agency responsible for the evaluation, publication and development of rules on invasive plant species for the purpose of protecting the health of native species, the environment, commercial agriculture, forest crop production, or human health in New Hampshire. New Hampshire's Prohibited Invasive Plant Species List identifies 35 species. These invasive species are provided in Table E.7-26 and include non-native species that have spread into native or minimally managed plant systems and can cause economic or environmental harm by developing self-sustaining populations and becoming dominant and/or disruptive to those systems.

Table E.7-26. Invasive Plant Species in Massachusetts and Prohibited Invasive Plant Species in New Hampshire

Common Name	Scientific Name	Common Name	Scientific Name
Norway maple	*Acer platanoides*	Creeping jenny	*Lysimachia nummularia*
Sycamore maple	*Acer pseudoplatanus*	Purple loosestrife	*Lythrum salicaria*
Bishop's goutweed	*Aegopodium podagraria*	Variable water-milfoil	*Myriophyllum heterophyllum*
Tree of heaven	*Ailanthus altissima*	European water-milfoil	*Myriophyllum spicatum*
Garlic mustard	*Alliaria petiolata*	Reed canary-grass	*Phalaris arundinacea*
Japanese barberry	*Berberis thunbergii*	Common reed	*Phragmites australis*
Carolina fanwort	*Cabomba caroliniana*	Japanese knotweed	*Polygonum cuspidatum*
Oriental bittersweet	*Celastrus orbiculatus*	Crisped pondweed	*Potamogeton crispus*
Black swallow-wort	*Cynanchum louiseae*	Lesser celandine	*Ranunculus ficaria*
Autumn olive	*Elaeagnus umbellata*	Common buckthorn	*Rhamnus cathartica*
Winged euonymus	*Euonymus alatus*	Black locust	*Robinia pseudoacacia*
Leafy spurge	*Euphorbia esula*	Multiflora rose	*Rosa multiflora*
European buckthorn	*Frangula alnus*	Water-chestnut	*Trapa natans*
Sea or horned poppy	*Glaucium flavum*	European black alder	*Alnus glutinosa*
Dame's rocket	*Hesperis matronalis*	European barberry	*Berberis vulgaris*
Yellow iris	*Iris pseudacorus*	Spotted knapweed	*Centaurea stoebe ssp. micranthos*
Broad-leaved pepperweed	*Lepidium latifolium*	Pale swallow-wort	*Cynanchum rossicum*
Japanese honeysuckle	*Lonicera japonica*	Giant hogweed	*Heracleum mantegazzianum*
Morrow's honeysuckle	*Lonicera morrowii*	Ornamental jewelweed	*Impatiens glandulifera*
Bell's honeysuckle	*Lonicera x bella*	Japanese stilt grass	*Microstegium vimineum*
Amur honeysuckle	*Lonicera maackii*	Blunt-leaved privet	*Ligustrum obtusifolium*
Tartarian honeysuckle	*Lonicera tatarica*	Common privet	*Ligustrum vulgare*
Mile-a-minute weed	*Persicaria perfoliata*	Bohemia knotweed	*Reynoutria x bohemica*
Kudzu	*Pueraria montana*	Reed sweet grass	*Glyceria maxima*
Giant knotweed	*Reynoutria sachalinensis*	--	--

Sources: Commonwealth of Massachusetts 2020; New Hampshire Department of Agriculture, Markets & Food, Division of Plant Industry 2017; IPANE Undated

As part of the 2019 and 2020 relicensing studies, ten plant species, which are designated as invasive or prohibited species (Commonwealth of Massachusetts 2020; New Hampshire Department of Agriculture, Markets & Food, Division of Plant Industry 2017), were incidentally observed in the Project's vicinity:

- Tree of heaven
- Japanese barberry
- Japanese knotweed
- Oriental bittersweet
- Autumn olive
- Winged euonymus
- Japanese honeysuckle
- Purple loosestrife
- Common buckthorn, and
- Black locust

E.7.4.1.4 Wetland, Riparian, and Littoral Habitats

Wetlands are generally defined as those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support vegetation typically adapted for life in saturated soil conditions. Most formal wetland definitions emphasize three primary components that define wetlands: the presence of water, unique soils, and hydrophytic vegetation. The USFWS (Cowardin et al. 1979) defines wetlands as follows:

> *…lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For purposes of this classification wetlands must have been one or more of the following three attributes: (1) at least periodically, the land supports predominately hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some point during the growing season of the year.*

Riparian habitats are areas that support vegetation found along waterways such as lakes, reservoirs, rivers, and streams. The boundary of the riparian area and the adjoining uplands is gradual and not always well defined. However, riparian areas differ from the uplands because of their high levels of soil moisture, frequency of flooding, and unique assemblage of plant and animal communities (Virginia State University 2000). These habitats can range from mature forests to areas covered by emergent vegetation and shrubs. Riparian habitats are unique because of their linear form and because they process large fluxes of energy and materials from upstream systems (Mitsch and Gosselink 1993). Riparian areas and the associated vegetation provide important habitat for wildlife and often contain a higher number of species, both plant and animal, than surrounding upland areas due to the proximity to water. These areas are also important avian habitats for resident and migratory birds. Riparian habitats typically function as travel corridors for migratory wildlife species. The riparian zone serves as the primary interface between riverine and upland habitats, influencing both the primary productivity and food resources within a river. Primary wildlife resources associated with riparian habitats include early spring plant growth in lowland riparian habitats, which provide food sources for migrating birds, white-tailed deer, and other wildlife species.

The USFWS, MADEP, and the NHDES have jurisdiction over wetlands within the Project area. The MADEP's and NHDES's wetland definition is consistent with the USFWS' wetland definition.

Terrestrial habitat conditions in the Project area and upstream along the Merrimack River are largely a result of land use, especially of urban and suburban development (Boott Mills 1980). Based on USFWS National Wetland Inventory (NWI) mapping, wetlands along the Merrimack River primarily consist of low-lying areas near and adjacent to the river, with other isolated wetlands farther away from the river proper. The USEPA has designated the Merrimack River from Franklin, New Hampshire, to Lowell, Massachusetts, as a Priority Waterbody/Wetland due to its importance to waterfowl and fish populations (Carley 2001 as cited in USACE 2003).

There are MADEP and NHDES wetlands and NWI wetlands encompassed within, adjacent to, or in close proximity to the Project boundary. Most of the MADEP, NHDES, and NWI mapped wetland boundaries overlay each other[22]. Within the current Project boundary there are approximately 739.2 acres of MADEP wetland, approximately 6.4 acres of NHDES wetland, and approximately 1,659 acres of NWI wetlands. The 745.6 acres of MADEP and NHDES wetlands are mostly encompassed within the 1,659 acres of NWI wetlands (MassGIS 2018; NH GRANIT undated).

Wetlands currently mapped by the USFWS NWI within the proposed Project boundary are presented in Figure E.7-23 through Figure E.7-24 and are summarized in Table E.7-27. Table E.7-27 provides mapping code descriptions for the NWI codes found on the wetland base maps (USFWS 2020a). The wetlands directly surrounding the Lowell Project are largely considered riverine wetlands with an unconsolidated bottom (Figure E.7-23 through Figure E.7-24). Riverine wetlands include all wetlands and deepwater habitats contained within a channel, with two exceptions: (1) wetlands dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and (2) habitats with water containing ocean-derived salts of 0.5 parts per thousand (or greater (Cowardin et al. 1979).

According to a review of GIS data (Massachusetts Bureau of Geographic Information [MassGIS]), there are no Massachusetts Natural Heritage and Endangered Species Program certified vernal pools within the Project boundary. Potential vernal pools were also identified using GIS data. According to MassGIS (2018), two potential vernal pools are located within 100 feet of the Project boundary, but not within the Project boundary.

No formal survey data on wetlands at or near the Project is available. However, based on observations made during the Recreation and Aesthetics Study, as well as during other relicensing studies, riparian vegetation within the Project area appears to be consistent with these areas of New Hampshire and Massachusetts. Where steep banks present themselves, the riparian corridor is narrow with wetland vegetation only occurring immediately adjacent to the river/land interface. Where the shoreline is more gradual and the Merrimack River floodplain extends away from the current river course, palustrine wetlands cover areas of former oxbows, floodplain, and low-lying areas.

[22] The NHDES wetland data GIS layer only included data for the Palustrine System within the Project boundary.

Massachusetts floodplain communities are typically dominated by river birch (*Betula nigra*) associations (USACE 2003). Development activity is contributing to the decline of these riparian communities in Massachusetts (Carley 2001 as cited in USACE 2003). The palustrine forested wetland habitats located within and adjacent to the Project boundary are primarily dominated by broad-leaved deciduous subclasses located along forested floodplains. These areas are characterized by their flood regime; lower areas are annually flooded in spring, whereas higher areas are flooded irregularly. Common trees include silver maple, red maple, green ash (*Fraxinus pennsylvanica*), and American elm. The shrub layer may include silky dogwood (*Cornus amomum*) and buttonbush (*Cephalanthus occidentalis*). Common herbaceous species may include sensitive fern (*Onoclea sensibilis*), false nettle (*Boehmeria cylindrica*), water hemlock (*Cicuta maculata*), swamp candles (*Lysimachia terrestris*), and water parsnip (*Sium suave*) (Swain 2020).

Figure E.7-23. Wetlands in the Vicinity of the Lowell Hydroelectric Project and Proposed Project Boundary

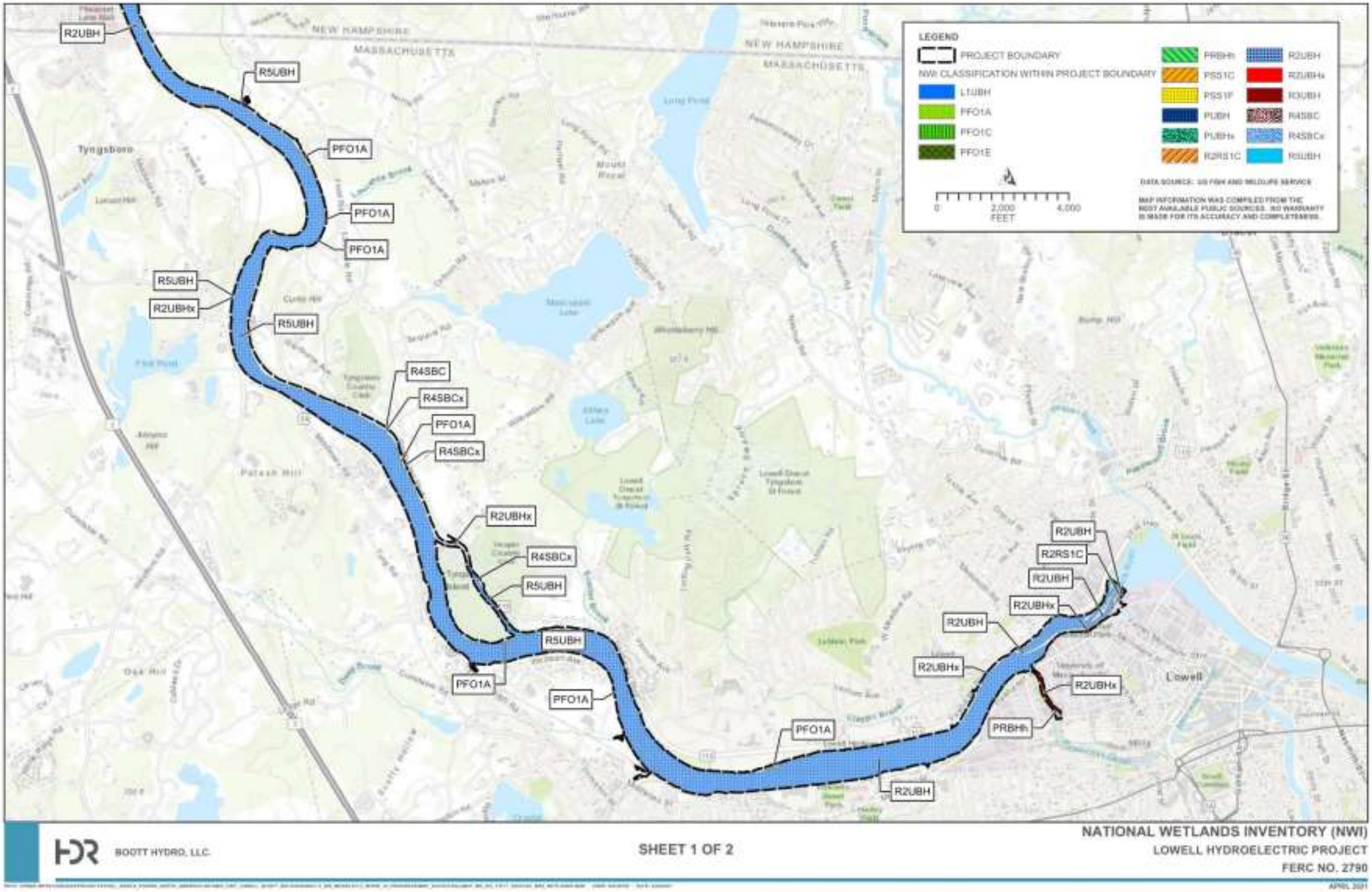


Figure E.7-24. Wetlands in the Vicinity of the Lowell Hydroelectric Project and Proposed Project Boundary

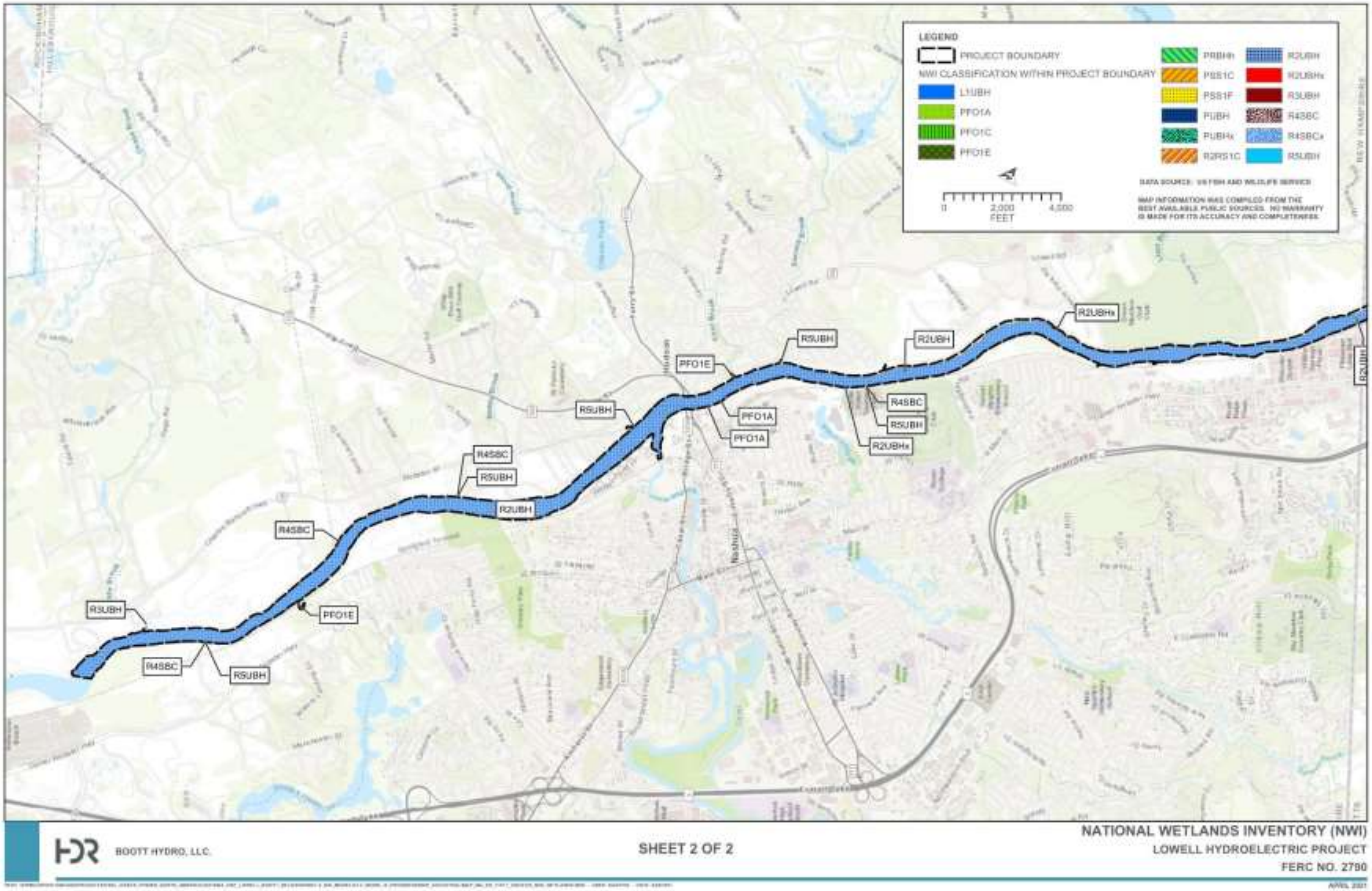


Table E.7-27. National Wetlands Inventory Classification System

Wetlands Code	System	Subsystem	Class	Subclass	Water Regime	Qualifier
R2UBH	Riverine	Lower Perennial	Unconsolidated Bottom	--	Permanently Flooded	--
R2UBHx	Riverine	Lower Perennial	Unconsolidated Bottom	--	Permanently Flooded	Excavated
R3UBH	Riverine	Upper Perennial	Unconsolidated Bottom	--	Permanently Flooded	--
R2RS1C	Riverine	Lower Perennial	Rocky Shore	Bedrock	Seasonally Flooded	--
R4SBC	Riverine	Intermittent	Streambed	--	Seasonally Flooded	--
R4SBCx	Riverine	Intermittent	Streambed	--	Seasonally Flooded	Excavated
R5UBH	Riverine	Unknown Perennial	Unconsolidated Bottom	--	Permanently Flooded	--
PUBH	Palustrine	--	Unconsolidated Bottom	--	Permanently Flooded	--
PUBHx	Palustrine	--	Unconsolidated Bottom	--	Permanently Flooded	Excavated
L1UBH	Lacustrine	Limnetic	Unconsolidated Bottom	--	Permanently Flooded	--
PFO1A	Palustrine	--	Forested	Broad-leaved Deciduous	Temporarily Flooded	--
PFO1C	Palustrine	--	Forested	Broad-leaved Deciduous	Seasonally Flooded	--
PFO1E	Palustrine	--	Forested	Broad-leaved Deciduous	Seasonally Flooded/ Saturated	--
PSS1F	Palustrine	--	Scrub-Shrub	Broad-leaved Deciduous	Semipermanently Flooded	--
PSS1C	Palustrine	--	Scrub-Shrub	Broad-leaved Deciduous	Seasonally Flooded	--
PRBHh	Palustrine	--	Rock Bottom	--	Permanently Flooded	Diked/ Impounded

Source: USFWS 2020a.

E.7.4.1.5 Wildlife

The Merrimack River corridor provides habitat for a diversity of wildlife species. Diverse habitats such as wetlands, forests, fields, as well as the river and associated tributaries support a variety of species. The quality and types of habitat that the Merrimack River corridor provides is what dictates which wildlife species occupy and use it. The

Merrimack River mainstem is categorized as a large/great river habitat (Olivero and Anderson 2008). Large river habitats such as the Merrimack River support a diverse wildlife community which includes many of the mammalian, reptilian, and amphibian species found in northeastern North America.

Mammals

Mammals present in the vicinity of the Lowell Project are those commonly found throughout the region that are adapted to living near humans and urban areas. Some large mammal species that require extensive habitat areas, or species that require solitude, such as moose (*Alces alces*) and black bear (*Ursus americanus*), typically prefer less developed environments that are scarce in the lower Merrimack River corridor and the Lowell Project. White-tailed deer (*Odocoileus virginianus*) is the most common big game species in the Project vicinity, occurring in a wide variety of habitats ranging from forests to agricultural land. This species is most prevalent along forest edges characterized by brushy and woody vegetation, swamp borders, and areas interspersed with fields and woodland openings (DeGraaf and Yamasaki 2001; Doutt et al. 1977). Raccoon (*Procyon lotor*) are also common, especially along the riparian corridor associated with the Merrimack River within the Project vicinity. Other mammals present in the Project vicinity include furbearers, small game species, rodents, and bats. These wildlife species reside in many different habitat types such as woodland, scrub-shrub or early successional areas, and grassland areas; use of these areas may shift during different life stages and/or times or year (DeGraaf and Yamasaki 2001; Doutt et al. 1977).

Mammals typically found in woodland and riparian areas include northern raccoon, long-tailed weasel (*Mustela frenata*), eastern gray squirrel (*Sciurus carolinensis*), American mink (*Mustela vison*), and marten (*Martes martes*). Bat species may include the red bat (*Lasiurus borealis*), silver haired bat (*Lasionycteris noctivagans*), hoary bat (*Lasiurus cinereus*), and little brown bat (*Myotis lucifugus*). These mammals are normally found in woodland/riparian areas due to food requirements, predator/prey relationships, and a preference by several species for trees as den or nest sites (DeGraaf and Yamasaki 2001; Doutt et al. 1977).

Mammals typically found in grassland areas include the meadow vole (*Microtus pennsylvanicus*), house mouse (*Mus musculus*), and the deer mouse (*Peromyscus maniculatus*). Several species of bats also are likely to use these areas or manmade structures within these areas of the Project vicinity. Additionally, several species typical of grassland mammals can be found in multiple habitat types due to their generalized requirements. Coyotes, for example, use woodlands, wetlands, and grasslands in addition to scrub-shrub areas for foraging, dens, and travel corridors (DeGraaf and Yamasaki 2001; Doutt et al. 1977). Table E.7-28 lists the mammalian species potentially occurring in the vicinity of the Lowell Project. Those species that were observed during field studies performed at the Project are indicated with an asterisk (*).

Table E.7-28. Mammalian Species Potentially Occurring in the Vicinity of the Lowell Project.

Common Name	Scientific Name
Beaver	*Castor canadensis*
Big brown bat	*Eptesicus fuscus*
Black bear	*Ursus americanus*
Black rat	*Rattus rattus*
Bobcat	*Lynx rufus*
Coyote	*Canis latrans*
Deer mouse	*Peromyscus maniculatus*
Eastern chipmunk*	*Tamias striatus*
Eastern red bat	*Lasiurus borealis*
Ermine	*Mustela ermina*
Fisher	*Pekania pennanti*
Gray fox	*Urcyon cinereoargenteus*
Gray squirrel*	*Sciurus carolinensis*
Hairy-tailed mole	*Parascalops breweri*
Hoary bat	*Lasiurus cinereus*
House mouse*	*Mus musculus*
Little brown bat	*Myotis lucifugus*
Long-tail weasel	*Mustela frenata*
Long-tailed shrew	*Sorex dispar*
Masked shrew	*Sorex cinereus*
Meadow jumping mouse	*Zapus hudsonicus*
Meadow vole	*Microtus pennsylvanicus*
Mink	*Mustela vison*
Moose*~	*Alces alces*
Muskrat	*Ondatra zibethicus*
Northern flying squirrel	*Glaucomys sabrinus*

Common Name	Scientific Name
Northern short-tailed shrew	*Blarina brevicauda*
Norway rat	*Rattus norvegicus*
Porcupine	*Erethizon dorsatum*
Pygmy shrew	*Sorex hoyi*
Raccoon*	*Procyon lotor*
Red fox	*Vulpes vulpes*
Red squirrel*	*Tamiasciurus hudsonicus*
River otter	*Lontra canadensis*
Silver-haired bat	*Lasionycteris noctivagans*
Small-footed bat	*Myotis leibii*
Smoky shrew	*Sorex fumeus*
Snowshoe hare	*Lepus americanus*
Southern bog lemming	*Synaptomys cooperi*
Southern flying squirrel	*Glaucamys volans*
Southern red-backed vole	*Clethrionomys gapperi*
Star-nosed mole	*Condylura cristata*
Striped skunk	*Mephitis mephitis*
Tricolored bat	*Perimyotis subflavus*
Virginia opossum	*Didelphis virginiana*
Water Shrew	*Sorex palustris*
White-footed mouse	*Peronyscus leucopus*
White-tailed deer	*Odocoileus virginianus*
Woodchuck*	*Marmota monax*
Woodland jumping mouse	*Napaeozapus insignis*
Woodland vole	*Microtus pinetorum*

Sources: NHDFG 2015; DeGraaf and Yamasaki 2001.
Note: ~ A moose was tranquilized and relocated by Massachusetts Environmental Police officers from the Northern Canal on June 11, 2020 (CBS Boston News Undated).

Avifauna

The diversity of habitats in the Lowell Project and lower Merrimack River corridor provide breeding, migratory stopover, and wintering habitat for a high diversity of avifauna including neotropical songbirds, resident species, waterbirds, and waterfowl. Species such as the black capped chickadee (*Poecile atricapillus*), blue jay (*Cyanocitta cristata*), and northern flicker (*Colaptes auratus*), and an assortment of woodpeckers occur within the wooded areas of the Project vicinity. Birds that inhabit non-forested areas within the Project's area include American robin (*Turdus migratorius*) and mourning dove (*Zenaida macroura*). The Merrimack River corridor, including the Project's impoundment and adjacent wetlands, attracts a variety of waterfowl. Four species of waterfowl were observed throughout the area while conducting various relicensing studies associated with the Project: Canada goose (*Branta canadensis*), mallard (*Anas platyrhynchos*), black duck (*Anas rubripes*), and double-crested cormorant (*Phalacrocorax auritus*). Double-crested cormorants were observed on several occasions within the bypass reach as well as in the vicinity of the Pawtucket Dam. Mallards were also seen along the Project canals as well at the confluence of the Pawtucket Canal and Merrimack River.

The ruderal herbaceous/scrub-shrub/forested areas in the Project vicinity are typically utilized by common species that are adapted to a variety of habitat types and are tolerant of human disturbance (i.e., generalist species). Common species of these habitats include rock pigeon (*Columba livia*), mourning dove, blue jay, common crow (*Corvus brachyrhynchos*), black-capped chickadee, northern cardinal (*Cardinalis cardinalis*), chipping sparrow (*Spizella passerina*), tree sparrow (*S. arborea*), mockingbird (*Mimus polyglottos*), starling (*Sturnus vulgaris*), and house finch (*Carpodacus mexicanus*) (DeGraaf and Yamasaki 2001). Incidental species observations, documented by environmental scientists during site visits conducted during 2019 and 2020 relicensing studies, supports this.

Great egret (*Ardea alba*) and great blue heron (*Ardea herodias*) observations were noted while conducting various relicensing studies associated with the Project. These species were usually noted feeding in the bypass reach or flying in the general vicinity of the E.L. Field Powerhouse. Table E.7-29 lists bird species potentially occurring in the vicinity of the Lowell Project. Those species that were observed during field studies performed at the Project are indicated with an asterisk (*).

Table E.7-29. Avian Species Potentially Occurring in the Vicinity of the Lowell Project.

Common Name	Scientific Name
Alder flycatcher	*Empidonax alnorum*
American bittern	*Botaurus lentiginosus*
American black duck*	*Anas rubripes*
American coot	*Fulica americana*
American crow*	*Corvus brachyrhynchos*
American goldfinch*	*Carduelis tristis*

Common Name	Scientific Name
American kestrel	*Falco sparverius*
American redstart	*Setophaga ruticilla*
American robin*	*Turdus migratorius*
American woodcock	*Scolopax minor*
Bald eagle	*Haliaeetus leucocephalus*
Baltimore oriole	*Icterus galbula*
Barn swallow	*Hirundo rustica*
Belted kingfisher	*Megaceryle alcyon*
Black-billed cuckoo	*Coccyzus erythropthalmus*
Blackburnian Warbler	*Dendroica fusca*
Black-capped chickadee*	*Poecile atricapillus*
Black-throated Blue Warbler	*Dendroica caerulescens*
Black-crowned night heron	*Nycticorax nycticorax*
Black-throated Green Warbler	*Dendroica virens*
Blue jay*	*Cyanocitta cristata*
Blue-gray gnatcatcher	*Polioptila caerulea*
Blue-headed Vireo	*Vireo solitarius*
Bobolink	*Dolichonyx oryzivorus*
Broad-winged hawk	*Buteo platypterus*
Brown creeper	*Certhia americana*
Brown-headed cowbird	*Molothrus ater*
Brown thrasher	*Toxostoma rufum*
Bufflehead	*Bucephala albeola*
Canada goose*	*Branta canadensis*
Canvasback	*Aythya valisineria*
Carolina Wren	*Thryothorus ludovicianus*
Cedar waxwing	*Bombycilla cedrorum*
Chestnut-sided Warbler	*Dendroica pensylvanica*

Common Name	Scientific Name
Chimney Swift	*Chaetura pelagica*
Chipping Sparrow*	*Spizella passerina*
Common goldeneye	*Bucephala clangula*
Common grackle	*Quiscalus quiscula*
Common Merganser	*Mergus merganser*
Common nighthawk	*Chordeiles minor*
Common raven	*Corvus corax*
Common redpoll	*Acanthis flammea*
Common Yellowthroat	*Geothlypis trichas*
Cooper's hawk	*Accipiter cooperii*
Dark-eyed junco	*Junco hyemalis*
Double-crested cormorant*	*Phalacrocorax auritus*
Downy Woodpecker	*Picoides pubescens*
Eastern Bluebird	*Sialia sialis*
Eastern Kingbird	*Tyrannus tyrannus*
Eastern phoebe	*Sayornis phoebe*
Eastern screech owl	*Megascops asio*
Eastern Wood-Pewee	*Contopus virens*
European Starling*	*Sturnus vulgaris*
Evening grosbeak	*Coccothraustes vespertinus*
Field sparrow	*Spizella pusilla*
Gadwall	*Mareca strepera*
Golden-crowned kinglet	*Regulus satrapa*
Golden eagle	*Aquila chrysaetos*
Gray catbird	*Dumetella carolinensis*
Great blue heron*	*Ardea herodias*
Greater scaup	*Aythya marila*
Great crested flycatcher	*Myiarchus crinitus*

Common Name	Scientific Name
Great horned owl	*Bubo virginianus*
Great egret*	*Ardea alba*
Green heron	*Butorides virescens*
Hairy Woodpecker	*Picoides villosus*
Hermit thrush	*Catharus guttatus*
Herring gull	*Larus argentatus*
Horned grebe	*Podiceps auritus*
House finch*	*Carpodacus mexicanus*
House sparrow*	*Passer domesticus*
House Wren	*Troglodytes aedon*
Indigo Bunting	*Passerina cyanea*
Killdeer	*Charadrius vociferus*
Least bittern	*Ixobrychus exilis*
Least flycatcher	*Empidonax minimus*
Long-eared owl	*Asio otus*
Louisiana Waterthrush	*Seiurus motacilla*
Magnolia Warbler	*Dendroica magnolia*
Mallard*	*Anas platyrhynchos*
Mockingbird*	*Mimus polyglottos*
Mourning dove*	*Zenaida macroura*
Mourning warbler	*Oporornis philadelphia*
Northern cardinal*	*Cardinalis cardinalis*
Northern flicker*	*Colaptes auratus*
Northern goshawk	*Accipiter gentilis*
Northern parula	*Setophaga americana*
Northern saw-whet owl	*Aegolius acadicus*
Northern shrike	*Lanius borealis*
Northern shoveler	*Spatula clypeata*

Common Name	Scientific Name
Northern waterthrush	*Seiurus noveboracensis*
Olive-sided flycatcher	*Contopus cooperi*
Orchard oriole	*Icterus spurius*
Osprey	*Pandion haliaetus*
Ovenbird	*Seiurus aurocapilla*
Pied-billed grebe	*Pied-billed grebe*
Pileated woodpecker	*Dryocopus pileatus*
Pine siskin	*Spinus pinus*
Purple finch	*Carpodacus purpureus*
Red-bellied woodpecker	*Melanerpes carolinus*
Red-breasted nuthatch	*Sitta canadensis*
Red crossbill	*Loxia curvirostra*
Red-eyed vireo	*Vireo olivaceus*
Redhead	*Aythya americana*
Red-shouldered hawk	*Buteo lineatus*
Red-tailed hawk*	*Buteo jamaicensis*
Red-winged blackbird	*Agelaius phoeniceus*
Ring-billed gull	*Larus delawarensis*
Ring-necked duck	*Aythya collaris*
Rock pigeon*	*Columba livia*
Rose-breasted grosbeak	*Pheucticus ludovicianus*
Ruby-crowned kinglet	*Regulus calendula*
Ruby-throated hummingbird	*Archilochus colubris*
Ruddy duck	*Oxyura jamaicensis*
Ruffed grouse	*Bonasa umbellus*
Sandhill crane	*Antigone canadensis*
Savannah sparrow	*Passerculus sandwichensis*
Scarlet tanager	*Piranga olivacea*

Common Name	Scientific Name
Sharp-shinned hawk	*Accipiter striatus*
Short-eared owl	*Asio flammeus*
Snow bunting	*Plectrophenax nivalis*
Snow goose	*Anser caerulescens*
Snowy owl	*Bubo scandiacus*
Song sparrow	*Melospiza melodia*
Sora	*Porzana carolina*
Spotted sandpiper	*Actitis macularius*
Swainson's thrush	*Catharus ustulatus*
Swamp sparrow	*Melospiza georgiana*
Tree sparrow*	*Spizella arborea*
Tree swallow	*Tachycineta bicolor*
Tufted titmouse	*Baeolophus bicolor*
Turkey vulture	*Cathartes aura*
Veery	*Catharus fuscescens*
Virginia rail	*Rallus limicola*
Warbling vireo	*Vireo gilvus*
White-breasted nuthatch*	*Sitta carolinensis*
White-winged crossbill	*Loxia leucoptera*
Wild turkey	*Meleagris gallopavo*
Wilson's warbler	*Cardellina pusilla*
Willow flycatcher	*Empidonax traillii*
Wood duck	*Aix sponsa*
Wood thrush	*Hylocichla mustelina*
Yellow warbler	*Dendroica petechia*
Yellow-bellied flycatcher	*Empidonaz flaviventris*
Yellow-bellied sapsucker	*Sphyrapicus varius*
Yellow-billed cuckoo	*Coccyzus americanus*

Common Name	Scientific Name
Yellow-rumped warbler	*Dendroica coronata*
Yellow-throated vireo	*Vireo flavifrons*

Sources: NHDFG 2015; DeGraaf and Yamasaki 2001.
* Species observed during field studies performed at the Project.

Amphibians and Reptiles

Amphibians and reptiles are common and well represented in the Project vicinity. However, only three amphibian species were observed throughout the area while conducting various relicensing studies associated with the Project (Table E.7-30). Species typically found in wetland and open water areas include green frog (*Lithobates clamitans*), bullfrog (*L. catesbeianus*), northern spring peeper (*Pseudacris crucifer*), and the northern water snake (*Nerodia sipedon sipedon*) (DeGraaf and Rudis 1983; Tyning 1990; Hunter et al. 1999). These amphibians and reptiles are normally found in wetland and open water areas due to food and reproductive requirements.

Species typically found in woodland areas include: spotted salamander (*Ambystoma maculatum*), eastern newt (*Notophthalmus viridescens*), American toad (*Anaxyrus americanus*), gray treefrog (*Hyla versicolor*), wood frog (*Lithobates sylvaticus*), and the northern two-lined salamander (*Eurycea bislineata*) (DeGraaf and Rudis 1983; Tyning 1990; Hunter et al. 1999). These amphibians are normally found in woodland areas due to food and reproductive requirements. A list of herptile species observed, that may occur, or may utilize habitat in the vicinity of the Project is included in Table E.7-30. Those species that were observed during field studies performed at the Project are indicated with an asterisk (*).

Table E.7-30. List of Herptile Species Observed or Anticipated to Occur in the Project Vicinity

Common Name	Scientific Name
Amphibians	
American toad*	*Anaxyrus americana*
Blue-spotted salamander	*Ambystoma laterale*
Bullfrog*	*Lithobates catesbeiana*
Dusky salamander	*Desmognathus fuscus*
Eastern spadefoot	*Scaphiopus holbrookii*
Four-toed salamander	*Hemidactylium scutatum*
Fowler's toad	*Anaxyrus fowleri*
Gray treefrog	*Hyla versicolor*

Common Name	Scientific Name
Green frog*	*Lithobates clamitans melanota*
Marbled salamander	*Ambystoma opacum*
Northern leopard frog	*Lithobates pipiens*
Northern spring salamander	*Gyrinophilus porphyriticus*
Pickerel frog	*Lithobates palustris*
Redback salamander	*Plethodon cinereus*
Red-spotted newt	*Notophthalmus viridescens*
Spotted salamander	*Ambystoma maculatum*
Spring peeper	*Pseudacris crucifer*
Two-lined salamander	*Eurycea bislineata*
Wood frog	*Lithobates sylvatica*
Reptiles	
Black racer	*Coluber constrictor*
Bog turtle	*Glyptemys muhlenbergii*
Blanding's turtle	*Emydoidea blandingii*
Brown snake	*Storeria dekayi*
Common garter snake	*Thamnophis sirtalis*
Common musk turtle	*Sternotherus odoratus*
Eastern box turtle	*Terrapene carolina*
Eastern gartersnake	*Thamnophis sirtalis*
Eastern hognose snake	*Heterodon platirhinos*
Eastern ratsnake	*Pantherophis alleghaniensis*
Milk snake	*Lampropeltis triangulum*
Northern water snake	*Nerodia sipedon*
Painted turtle	*Chrysemys picta*
Red-bellied snake	*Storeria occipitomaculata*
Ribbon snake	*Thamnophis sauritus*
Ringneck snake	*Diadophis punctatus*

Common Name	Scientific Name
Smooth green snake	*Liochlorophis vernalis*
Snapping turtle	*Chelydra serpentina*
Spotted turtle	*Clemmys guttata*
Wood turtle	*Glyptemys insculpta*

Source: NHDFG 2015; DeGraaf and Rudis 1983; Jackson et al. 2010.
* Species observed during field studies performed at the Project.

E.7.4.2 Environmental Analysis

FERC's SD2 identified effects of continued Project operations on terrestrial resources as potential resource issues. Specifically, SD2 identified the following potential resource issues related to terrestrial resources to be analyzed for site-specific effects:

- Effects of continued project operation on riparian, littoral, and wetland habitat and associated wildlife.
- Effects of continued project operation, including maintenance activities (e.g., vegetation management) on wildlife habitat and associated wildlife.
- Effects of continued project operation and maintenance on the introduction and persistence of invasive plants within the Project boundary.

E.7.4.2.1 Effects of Continued Project Operation on Riparian, Littoral, and Wetland Habitat and Associated Wildlife

The types of wetlands bordering the Project generally reflect the expectations for the natural community in this area. The Project operates in ROR mode, and experiences seasonal and annual variations in flows based on natural hydrologic conditions in the Merrimack River Basin. Boott also proposes to continue to adhere to the requirements of the Project's existing Crest Gate Operation Plan, which provides for a stable impoundment level maintained over a wide range of flows. Therefore, the proposed operation of the Project will have negligible effects on the flow regime and wetland and riparian habitats in the Merrimack River.

Additionally, the occurrence and distribution of wildlife resources in the Project area is generally unrelated to Project operations, and Project operations have little potential to impact wildlife resources within and bordering the Project. Since the Licensee is not proposing changes to the existing baseline conditions or changes to the operation of the Project, continued operation of the Project as proposed by the Licensee is not expected to have any adverse effects on wetland, riparian, or littoral habitat or associated wildlife.

E.7.4.2.2 Effects of Continued Project Operation on Wildlife Habitat, Associated Wildlife, and the Introduction and Persistence of Invasive Plants

The operation of the Project has very little, if any, effect on the wildlife habitat or resources within and bordering the Project boundary, and the occurrence and distribution of wildlife resources in the Project area is generally unrelated to Project operations. Boott does however, conduct routine Project maintenance activities. Project maintenance activities are generally localized and minor in nature.

Many types of land uses contribute to the invasion and spread of non-native invasive species, including ground-disturbing activities and activities that promote the dispersal of weed seed. Roads, rivers, streams, agriculture, farming/ranching, recreation, residential, and commercial developments all contribute to the spread of invasive species.

Continued Project operations are not expected to contribute to the spread of invasive species. As noted above, the botanical resources located within the Project boundary have developed under the current operating regime and are generally stable, mature, and well established. Boott's routine vegetation management practices typically involve mechanical vegetation removal around Project facilities and the clearing of hazard trees as necessary. Boott is not proposing to conduct additional ground-disturbing activities such as road construction or land-clearing that would facilitate the spread of invasive botanical species within the Project boundary. The continued operation and maintenance of the Project as proposed by the Licensee is not expected to have any adverse effects on the wildlife habitat and associated wildlife, or the introduction and persistence of invasive plants within the Project boundary.

E.7.4.3 Proposed Environmental Measures

Boott proposes to continue operations of the Project with certain PM&E as outlined above in Section E.6.2.

E.7.4.4 Unavoidable Adverse Impacts

Continued operation of the Project as proposed by the Licensee will not result in any unavoidable adverse effects on terrestrial botanical or wildlife resources.

E.7.5 Rare, Threatened and Endangered Species

The subsections below describe RTE species in the vicinity of the Project and consider the effects of continued operation of the Project as proposed by the Licensee on these resources. Descriptions of the affected environment, the environmental analysis, the proposed environmental measures, and the identification of unavoidable adverse effects were developed based on available data presented in the Licensee's PAD, and the:

- Fish Assemblage Study (NAI 2021d)
- Downstream American Eel Passage Assessment (NAI 2021a)

These reports are included in Appendix B of this exhibit.

E.7.5.1 Affected Environment

E.7.5.1.1 Federal-listed Species

As part of the environmental evaluation conducted for the Project, the USFWS Information, Planning, and Consultation System (IPaC System) identified a list of species under the USFWS's jurisdiction that are known or expected to be on or near the Project area. Based on a search of the USFWS IPaC system for ESA-listed species, northern long-eared bat (*Myotis septentrionalis*) is ESA-listed as threatened and may occur in the Project area; the habitat requirements and distribution of the species are described below. No ESA-listed aquatic species are identified in the USFWS database as being known or believed to occur in the Project area (USFWS 2020b). In addition to this species, the bald eagle (*Haliaeetus leucocephalus*) is known to occur as a transient in the Project vicinity; this species is protected under the Federal Bald and Golden Eagle Protection Act[23] (and is separately listed by the Commonwealth of Massachusetts and New Hampshire; see below).

Northern long-eared bat

The northern long-eared bat is found across much of eastern and north-central United States, and all Canadian provinces from the Atlantic Ocean west to the southern Yukon Territory and British Columbia (USFWS 2013). It is a medium-sized bat, measuring 3 – 3.7 inches, with a wingspan of 9 or 10 inches. Its fur color can be medium to dark brown on the back and tawny to pale brown on the underside (USFWS 2013). The bat is distinguished by its long ears relative to other bats in the genus Myotis (USFWS 2013). The northern long-eared bat spends winters hibernating in caves and mines, preferring hibernacula with very high humidity. During the summer months, the northern long-eared bat prefers to roost singly or in colonies underneath bark, in cavities, or in the crevices of live or dead trees (USFWS 2013). Breeding begins in late summer or early fall when males swarm near hibernacula. After a delayed fertilization, pregnant females migrate to summer colonies where they roost and give birth to a single pup. Young bats start flying

[23] 16 U.S.C. 668, *et seq.*

18 – 21 days after birth, and adult northern long-eared bats can live up to 19 years (USFWS 2013).

Northern long-eared bats emerge at dusk and fly through the understory of forested hillsides feeding on moths, flies, leafhoppers, caddisflies, and beetles. They also feed by gleaning motionless insects from vegetation and water (USFWS 2013).

The most severe and immediate threat to the northern long-eared bat is white-nose syndrome. As a result of this disease, numbers have declined by 99 percent in the northeast. Other significant sources of mortality include impacts to hibernacula from human disturbance. Loss or degradation of summer habitat as a result of highway or commercial development, timber management, surface mining, and wind facility construction and operation can also contribute to mortality (USFWS 2015).

No Biological Opinions have been developed by the USFWS for the northern long-eared bat in the Project area. In addition, no status reports or recovery plans were located for this species in the vicinity of the Project.

The USFWS has not designated critical habitat for the northern long-eared bat in the vicinity of the Project.

E.7.5.1.2 State-listed Species

Listings of the applicable state-listed threatened, endangered, and candidate species, as well as species of special concern, candidate species, and communities (RTE species) were obtained by request from map and database information provided by the Massachusetts Natural Heritage and Endangered Species Program (Massachusetts NHESP) and the New Hampshire Natural Heritage Bureau (New Hampshire NHB). In addition, habitat information was provided by the New Hampshire NHB, Massachusetts NHESP, as derived from the New Hampshire NHB's and Massachusetts NHESP's fact sheets, and flora manuals (e.g., Magee and Ahles 1999). Specific to the Project area, the potential presence of RTE species was determined by consulting with the Massachusetts NHESP and the New Hampshire NHB during development of the PAD. Table E.7-31 lists the state-listed species and communities that the Commonwealth of Massachusetts and the State of New Hampshire list as potentially occurring within the Project area and provides habitat requirements information.

Table E.7-31. State-listed threatened, endangered, species of special concern, candidate species, and communities potentially occurring within the Project vicinity.

Scientific Name	Common Name	Status[a,b]	Habitat/Notes
Massachusetts			
Haliaeetus leucocephalus	Bald Eagle	T	Large lakes, rivers; large riparian trees for nesting, roosting (DeGraaf and Yamasaki 2001).
Stylurus amnicola	Riverine Clubtail	E	Riverine clubtails inhabit primarily medium to large rivers. Although most species of *Stylurus* fly late in the season, riverine clubtails are on the wing from late June through mid-August (Massachusetts NHESP 2015).

Scientific Name	Common Name	Status[a,b]	Habitat/Notes
New Hampshire			
Alasmidonta varicosa	Brook Floater	E	Sections of stream with low to moderate flow and stable substrates (Nedeau et al. 2000).
Anguilla rostrata	American Eel	SC	American eels are opportunistic carnivores, selecting a range of prey items from small aquatic insects and crustaceans to larger macroinvertebrates and fish (Ross et al. 2001). Yellow eels associate with pools or backwater habitats and often have relatively small home ranges (Gunning and Shoop 1962).
Haliaeetus leucocephalus	Bald Eagle	SC	Large lakes, rivers; large riparian trees for nesting, roosting (DeGraaf and Yamasaki 2001).
Emydoidea blandingii	Blanding's Turtle	E	Permanent, shallow, dark waters with abundant vegetation; marshes, bogs, ditches, ponds, swamps, also in slow moving rivers and protected coves (DeGraaf and Yamasaki 2001).
Heterodon platirhinos	Eastern Hognose Snake	E	Where sandy soils predominate, such as beaches, open fields, dry, open pine or deciduous woods (DeGraaf and Yamasaki 2001).
Sturnella magna	Eastern Meadowlark	T	Large grassy fields of intermediate height and density but also uses grassy meadows, hay fields, tall-grass prairies, agricultural fields and open weedy orchards (DeGraaf and Yamasaki 2001).
Ammodramus savannarum	Grasshopper Sparrow	T	Generally prefers moderately open grasslands with patchy bare ground: dry hayfields, especially those with alfalfa and red clover, weedy fallow fields, prairies, and coastal dunes in Massachusetts (DeGraaf and Yamasaki 2001).
Sylvilagus transitionalis	New England Cottontail	E	Brushy areas, open woodlands, swamps, mountains, beaches, and open lands (DeGraaf and Yamasaki 2001).
Lithobates pipiens	Northern Leopard Frog	SC	Wet open meadows and fields and wet woods during summer months, including river floodplains (DeGraaf and Yamasaki 2001).
Petromyzon marinus	Sea Lamprey	SC	In fresh water, sea lampreys use river reaches with gravel substrate for spawning. Spawning habitat is similar to that used by salmon, occurring at the upstream end of riffles and the tail end of pools (NHDFG undated *a*).

Scientific Name	Common Name	Status[a,b]	Habitat/Notes
Porzana carolina	Sora	SC	Prefers freshwater marshes with shallow to intermediate water depths and dominated by emergent vegetation (DeGraaf and Yamasaki 2001).
Pooecetes gramineus	Vesper Sparrow	SC	Sparsley vegetated dry uplands such as short-grass meadows, grazed pastures, hayfields, grain fields, dry open uplands, and burned and cutover areas (DeGraaf and Yamasaki 2001).
Viola pedata var. pedata	Bird-foot Violet	T	This species occurs in sandplains, disturbed openings, dry forests, and thin woods. Threats would include direct destruction of the plants or major alterations in their habitat (Magee and Ahles 1999; New Hampshire NHB 2018).
*Cenchrus longispinus**	Long-spined Sandbur	E	This species grows in dry, sandy soil of fields, roadsides, waste areas, beaches, river flats, sandplains, and disturbed openings, and is sensitive to disturbances that eliminate its habitat (Magee and Ahles 1999; New Hampshire NHB 2018).
Betula nigra	River Birch	T	This species grows along rivers and streambanks and the population could be deleteriously affected by any project activities that alter the hydrology of its habitat, by increased sedimentation, and by increased nutrients/pollutants in stormwater runoff (Magee and Ahles 1999; New Hampshire NHB 2018).
Lupinus perennis ssp. perennis	Wild Lupine	T	This wildflower grows in extremely dry, sandy openings. It is tolerant of surrounding disturbance and depends upon periodic mowing (or, historically, wildfire) to eliminate trees that would otherwise shade it out (New Hampshire NHB 2018).
Eleocharis diandra	Wright's Spikesedge	E	Wright's spikesedge is found along gently sloping freshwater shorelines and marshes. It commonly occurs in disturbed, saturated soils of river edges, often in small depressions. It is typically found in the zone along the water's edge that undergoes spring flooding and is exposed in the summer. The species is primarily vulnerable to changes to the hydrology of its wetland habitat, especially alterations that change water levels. It may also be susceptible to increased pollutants and nutrients carried in stormwater runoff (Magee and Ahles 1999; New Hampshire NHB 2018; Massachusetts NHESP 2012).

Scientific Name	Common Name	Status[a,b]	Habitat/Notes
N/A	Hemlock Forest*	--	Hemlock forests typically occur on rocky, coarse, and/or thin soils poor in nutrients, including ravines, gorges, river and kame terraces, and other microsites below 2000 feet in elevation. Soils typically have welldeveloped E horizons (classic Spodosols), are very acidic, high in exchangeable aluminum, and low in available nitrogen and other nutrients. Threats include logging, introduction of invasive species, and direct destruction due to development (Sperduto and Nichols 2004; New Hampshire NHB 2018).
N/A	Highgradient Rocky Riverbank System	--	Threats are primarily changes to the hydrology of the river, land conversion and fragmentation, introduction of invasive species, and increased input of nutrients and pollutants (New Hampshire NHB 2018).

Sources: New Hampshire NHB 2018; Massachusetts NHESP 2018; MEOEEA 2018.
a: "E" = Endangered, "T" = Threatened, "SC" = Special Concern, "--" = an exemplary natural community, or a rare species tracked by New Hampshire NHB that has not yet been added to the official state list. An asterisk (*) indicates that the most recent report for that occurrence was more than 20 years ago.
b: The request to New Hampshire NHB included lands within the FERC Project boundary but did not specify a maximum linear distance from the Project boundary in which potential RTE species would be identified. Therefore, for the purposes of this Exhibit, the RTE project area in New Hampshire has been defined as all lands within the FERC Project boundary and lands within approximately 500 feet of the Project boundary.

Massachusetts NHESP Priority and Estimated Habitats

The Massachusetts NHESP identifies Priority Habitat based on the known geographical extent of habitat for all state-listed rare species, both plants and animals, and is codified under the Massachusetts Endangered Species Act (MESA). Habitat alteration within Priority Habitat may result in a take of a state-listed species and is subject to regulatory review by the Massachusetts NHESP. Currently, a portion of the Project boundary, and adjacent terrestrial habitats outside the Project boundary, are listed as Massachusetts NHESP Priority Habitat (Priority Habitat 1987). This area extends from approximately 1.03 miles south of the New Hampshire border on the northern end to just south of the Greater Lowell Technical High School on the southern end along the Merrimack River.

The Massachusetts NHESP also identifies Estimated Habitats, which are a sub-set of the Priority Habitats, and are based on the geographical extent of habitat of state-listed rare wetlands wildlife and is codified under the Wetlands Protection Act (WPA), which does not protect plants. State-listed wetland wildlife species are protected under the MESA as well as the WPA. Currently, a portion of the Project boundary, and adjacent terrestrial habitats outside the Project boundary, are listed as Massachusetts NHESP Estimated Habitat (Estimated Habitat 1320). This area extends from approximately 1.03 miles south of the New Hampshire border on the northern end to just south of the Greater Lowell Technical High School on the southern end along the Merrimack River.

E.7.5.1.3 Identified Federal- and State-listed Species in the Project Area

Fish Species

State-listed fish species were identified through two primary studies, the Fish Assemblage Study and the Downstream American Eel Passage Assessment Study. The methods and results of these studies are presented in the Technical Report for the Fish Assemblage Study (NAI 2021d) and the Technical Report for the Downstream American Eel Passage Assessment (NAI 2021a), respectively, which were filed with the Commission on February 25, 2021.

In accordance with the approved study plan, Boott conducted a Fish Assemblage Study in 2019 to characterize the fish assemblage in areas affected by the Lowell Project, specifically the impoundment and bypassed reach. The study area for this fish community survey included the mainstem Merrimack River from the Pawtucket Dam to the upper extent of the Project's impoundment located approximately 23 river miles upstream, and the Project's 0.7-mile-long bypassed reach (NAI 2021d). Two State-listed species of special concern, the American eel and the sea lamprey, were identified. Boott captured 17 American eel upstream of the Pawtucket Dam by boat electrofishing and experimental gill net and also captured 33 American eel within the bypassed reach downstream of Pawtucket Dam by backpack electrofishing during the spring, summer and fall sampling in 2019. American eel represented 13.8% of the total electrofishing catch from the ledge channel habitat located in the lower portion of the Lowell bypassed reach. Additionally, Boott captured 21 sea lampreys upstream of Pawtucket Dam by boat electrofishing and experimental gill net during the spring, summer and fall sampling in 2019 (NAI 2021d).

Wildlife Species

No ESA-listed wildlife species (i.e., northern long-eared bat) were observed during field studies conducted in 2019 or 2020; although no specific surveys were conducted for this species.

E.7.5.1.4 Designated Critical Habitat

When a species is proposed for listing as endangered or threatened under the ESA, the USFWS must consider whether there are areas of habitat believed to be essential to the species' conservation. Those areas may be proposed for designation as Critical Habitat. Critical Habitat is a specific geographic area that contains features essential for the conservation of a threatened or endangered species and that may require special management and protection. No Critical Habitat has been designated under the ESA for terrestrial species in the Project vicinity (USFWS 2020b).

E.7.5.2 Environmental Analysis

FERC's SD2 identified effects of continued Project operations on threatened and endangered species as potential resource issues. Specifically, SD2 identified the following potential resource issues related to threatened and endangered species to be analyzed for site-specific effects:

- Effects of continued project operation and maintenance on the federally threatened northern long-eared bat.

One federally threatened mammal species, the northern long-eared bat, may occur within the Project area. This aerial insectivore may forage adjacent to Project waters in forested habitats in the summer but is not expected to be adversely affected as a result of Project operation. This bat species roosts in upland areas (live or snag trees, caves, etc.), outside of the range of potential Project operational affects. This bat species spends winters months in hibernacula and is not expected to be adversely affected by Project operations. There are no known hibernacula or roost trees for northern long-eared bat in the immediate vicinity of the Project's facilities. Additionally, the occurrence and distribution of terrestrial wildlife resources in the Project area is generally unrelated to operation of the Project. The operation of the Project as proposed is not expected to have any adverse effects on northern long-eared bat; however, in the event Boott performs maintenance activities at the Projects that could affect bat habitat, Boott will perform the required consultation and protection measures pursuant to applicable federal and state laws and regulations, including the Endangered Species Act.

Bald eagles are known to use the Merrimack River watershed for winter perching, roosting, and feeding activities and have been documented along the Merrimack River mainstem from Franklin to Nashua, New Hampshire, and throughout the Massachusetts portion of the basin (USACE 2003). Continued Project operations as proposed by the Licensee have a very low potential to impact bald eagles or roost trees. The occurrence and distribution of terrestrial wildlife resources in the study area is generally unrelated to Project operations. Boott conducts routine Project maintenance activities and manages formal Project recreation facilities at the Project. Project maintenance activities are generally localized and minor in nature.

Some State wildlife Species of Special Concern may potentially occur within the Project. These include several bird species and one amphibian species (northern leopard frog). All of the wildlife Species of Special Concern that have potential to occur within the Project area are highly mobile and are most likely to occur in the Project area for foraging (and, in some cases, breeding) during temperate months. The Licensee is proposing no fundamental changes in operation. As a result, and given that no RTE species have been documented within the Project boundary, continued operation of the Project is not expected to adversely affect RTE species.

E.7.5.3 Proposed Environmental Measures

Boott proposes continued operations of the Project with environmental PM&E measures which will protect rare, threatened and endangered species and their habitats. These measures include:

- Continue to operate the Project in ROR mode;
- Maintain a bypass reach minimum flow of 500 cfs via the Pawtucket Dam fish ladder during the fish passage season (typically May 1 – July 15), and 100 cfs outside of the fish passage season;
- Continued adherence to the requirements of the Project's existing Crest Gate Operation Plan;
- Install new trashracks or other fish exclusion facility at the E.L. Field Powerhouse, which will prevent the entrainment of outmigrating adult American eel.

E.7.5.4 Unavoidable Adverse Impacts

The occurrence and distribution of terrestrial wildlife and RTE resources in the study area is generally unrelated to Project operations. The continued operation of the Project as proposed by the Licensee is not expected to have any adverse effects on the northern long-eared bat. Routine Project maintenance activities that could affect bat habitat are generally localized. Bat foraging may take place over the impoundment and along the shoreline; however, the ROR operation of the Project will not affect the ability of bats to access foraging habitat or limit potential prey species (e.g., invertebrates).

E.7.6 Recreation and Land Use

The subsections below describe recreation and land use in the vicinity of the Project and consider the effects of continued operation of the Project as proposed by the Licensee on these resources. Descriptions of the affected environment, the environmental analysis, the proposed environmental measures, and the identification unavoidable adverse effects were developed based on available data presented in the Licensee's PAD, and the:

- Recreation and Aesthetics Study Report (HDR 2021a)
- Water Level and Flow Effects on Historic Resources Study Report (HDR 2021b)
- Resources, Ownership, Boundaries and Land Rights Study Report

However, Boott also notes that the Whitewater Boating and Access Study required by the Commission is on-going. Subsequent to completion of the study activities, Boott anticipates additional consultation with stakeholders.

E.7.6.1 Affected Environment

E.7.6.1.1 Project Recreation Facilities

Pursuant to existing License Article 38 and the FERC-approved Recreation Plan, Boott maintains one formal recreation area at the Project:

E.L. Field Powerhouse Visitor Center (Visitor Center)

The Visitor Center, located along the mainstem of the Merrimack River, offers a secured view of the interior of the turbine gallery and an interpretive display that provides information regarding the development, history, and operation of the Project, and nearby historic, natural, cultural, recreational resources, and other items of interest.

E.7.6.1.2 Recreation in the Project Area

The Project's primary features are located along the Merrimack River in the City of Lowell, Massachusetts. The Merrimack River watershed supports all or parts of approximately 200 communities with a total population of 2.6 million people (USEPA 2020b; USACE 2006). The Merrimack River provides numerous recreational opportunities to the residents of the communities along its banks but is also utilized by residents of major cities in the region, particularly residents from Boston (Nashua Regional Planning Commission [NRPC] 2008; NHDES 2019a; USACE 2006).

The Project dam is located at RM 41 on the Merrimack River, and the impoundment extends upstream approximately 16 miles to Cromwell's Falls in Litchfield and Merrimack, New Hampshire. The Project impoundment is characterized by the urban/industrialized cities of Nashua, New Hampshire and Lowell, Massachusetts. The Merrimack River provides extensive recreational opportunities, including boating, canoeing, kayaking, rowing, fishing, and swimming. Several parks and conservation areas in the vicinity of the Project afford additional recreation opportunities that include hiking, cross country skiing, picnicking, and bird watching. Recreational opportunities differ closer to the larger, more populated cities along the river.

Several project facilities are located within overlapping locally, state, and nationally designated parks and historic properties/preservation districts. Non-Project related recreational facilities and opportunities in the Project's vicinity include:

- Depot Street Boat Ramp
- Greely Park and Boat Ramp
- Lowell National Historic Park (LHNP)
- Lowell Heritage State Park
- Lowell-Dracut Tyngsborough State Forest
- Flints Pond Access
- Merrill Park
- Twin Bridge Park
- Moore's Falls Conservation Area
- John Bryant River Access
- Thornton's Ferry Boat Launch
- Litchfield State Forest
- Horse Hill Nature Preserve
- Leslie Bockes Memorial Forest
- New Hampshire Heritage Trail
- Chelmsford Boat Access
- Great Brook Farm State Park
- Warren H. Manning State Forest
- Billerica State Forest
- Carlisle State Forest
- Governor Thomas Dudley State Park
- Merrimack River Boat Access.

These and other non-Project related facilities are not owned or operated by Boott but are popular Merrimack River recreational areas. In addition, there are numerous informal access areas on Lowell Hydroelectric Project lands that are used by the public for access to the Merrimack River. Figure E.7-25 through Figure E.7-26 depict the wide range of recreational opportunities in the vicinity of the Project, which are described in more detail below.

Figure E.7-25. Recreation Opportunities in the Vicinity of the Lowell Hydroelectric Project

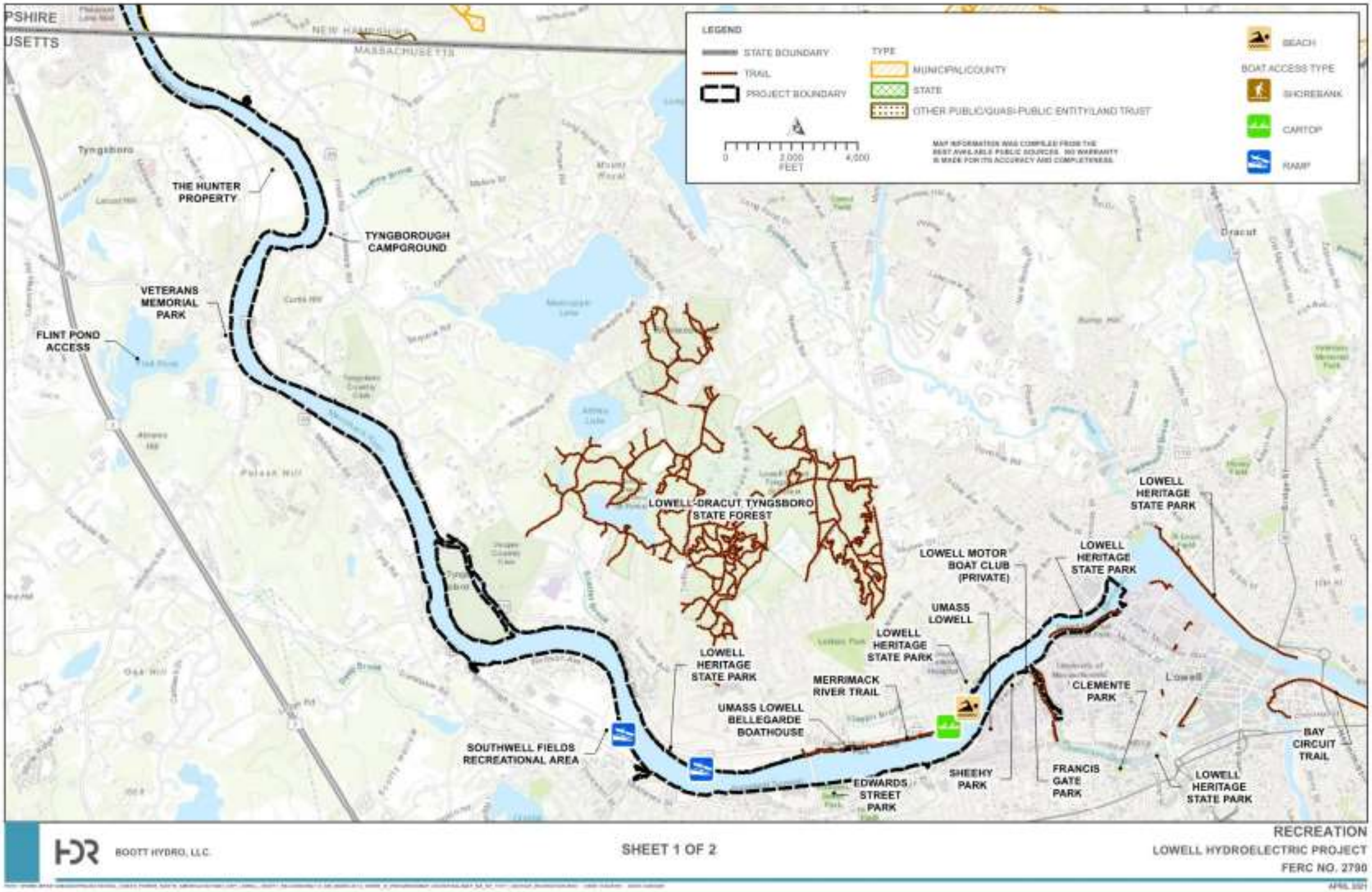
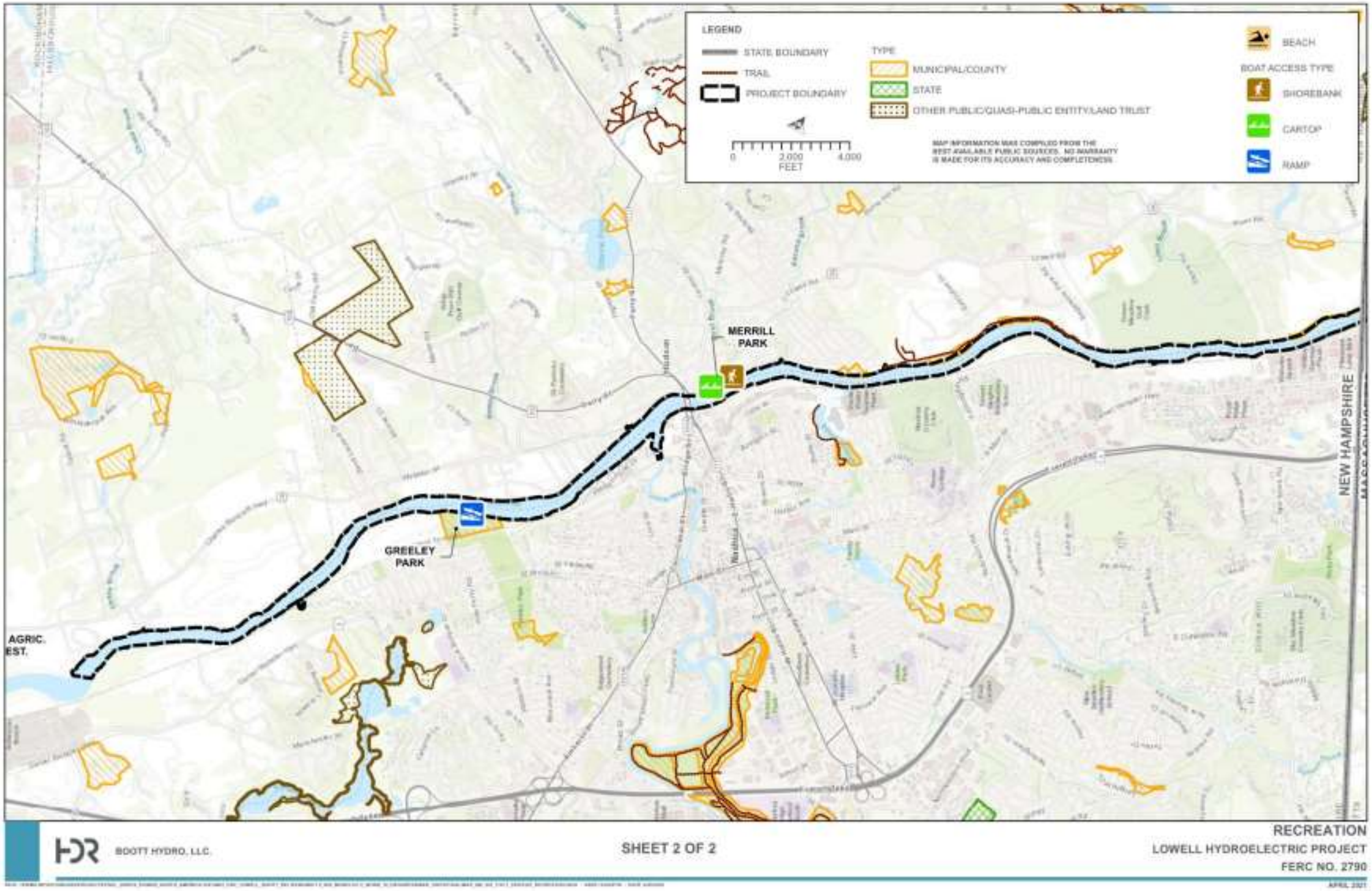


Figure E.7-26. Recreation Opportunities in the Vicinity of the Lowell Hydroelectric Project



E.7.6.1.3 Recreation Opportunities in New Hampshire

The State of New Hampshire reports many recreational uses of the Project impoundment, including fishing, canoeing, kayaking, rowing, and motor boating. Much of the Project impoundment is in Hillsborough County, New Hampshire, which has approximately 54,480 acres of recreation lands and 116 public access sites to the water (New Hampshire Department of Natural and Cultural Resources [NHDNCR] 2018). Most of the shore lands along the Merrimack River in New Hampshire are privately owned; therefore, recreation activities take place immediately on the Merrimack River (NRPC 2008). There are six known boat access facilities in New Hampshire with direct access to the Project impoundment. These facilities range in design from concrete ramps to shoreline access and are described below:

Moore's Falls Conservation Area: Moore's Falls Conservation Area offers shoreline fishing and car-top boating access to Moore's Falls upstream of the Project impoundment. Moore's Falls are a length of rapids on the Merrimack River which drop 6 feet in elevation over 650 feet in distance, which define the upstream extent of the Project impoundment. There are also walking trails through the woods, an old trolley track trail, multiple access points to the Merrimack River for fishing, educational information regarding environmental conservation, and birdhouses. Running along the east bank of the river are the remains of a historic lock structure constructed in the early 1800s. NHDES recommends this conservation area for angler fishing, as small and large mouth bass are often caught, as well as rainbow and brook trout, both of which are stocked by the NHFGD in the Lower Merrimack River (Middlesex Canal Association 2009; NHDES 2019a).

Depot Street Boat Ramp: The Depot Street Boat Ramp offers a carry-in boat ramp and fishing access to the Merrimack River and is managed by the Town of Merrimack. The trail to the river runs under railroad tracks. This access is suitable for motorboats, as the river slows from the rocky rapids upstream (NHDES 2019a; Merrimack Parks and Recreation 2020). There is also a scenic picnic area.

John Bryant River Access: The John Bryant River Access is a canoe/kayak car top facility managed by the Litchfield Recreation Commission. It provides fishing access, scenic views of the river, and birdwatching. It is available only to Town of Litchfield, New Hampshire residents (Litchfield Recreation Commission 2020).

Thornton's Ferry Boat Launch: Thornton's Ferry Boat Launch is owned by the Town of Merrimack and offers cartop carry-in boating and fishing access to the Merrimack River (NHFGD undated).

Greeley Park & Boat Ramp: Greeley Park is a 125-acre city park located in Nashua, New Hampshire. Greely Park offers many recreation amenities/facilities including baseball/softball fields, historical sites, picnic areas, playgrounds, restrooms, tennis courts, trails, and wading pools (NHFGD undated; City of Nashua 2020). In 2019, the City of Nashua issued an invitation to bid for reconstruction of the Greeley Park Boat Ramp, as well as construction of a gravel parking lot, placement of new signs, and three biological retention ponds. The work was scheduled for completion in July 2020 (NHFGD undated; City of Nashua 2019). A paved ramp at the north end of Greeley Park in

Nashua also allows access to the river for boaters. NHDES recommends this conservation area for angler fishing (NHDES 2019a).

Merrill Park: Merrill Park is a 9.3-acre city park located in Hudson, New Hampshire. It is adjacent to the east riverbank and Project boundary. The park is mostly forested with a few walking paths and picnic benches. It has a path which leads down to the Merrimack River, allowing hand-carry access for canoes or kayaks, or fishing (Town of Hudson undated).

In addition to the facilities mentioned above, the following facilities are within a 30-minute drive from the Project boundary and provide outdoor activities that include wildlife observation, driving for pleasure, sightseeing, day hiking, and jogging/running/walking:

Litchfield State Forest: The Litchfield State Forest is a 450-acre forest in Litchfield managed by the State of New Hampshire. It is located about 1.5 miles east of the Project boundary. The 1.3-mile Litchfield State Forest Trail provides comfortable walking and biking trails. Off trails provide an additional four miles of hiking, wildlife observation, and scenic opportunities. The trails are often used for cross country skiing in the winter (Litchfield Recreation Commission 2020; ExploreYourSpaces 2020).

Flints Pond Access: Flints pond is a 50-acre, warm water pond located in the Town of Hollis in New Hampshire. The pond is open to the public for fishing, kayaking, and canoeing in the summer. In the winter, ice fishing, snowshoeing, and snowmobiling are also popular. A boat ramp is available at the north end of the pond (Flints Pond Improvement Association 2015). Flints Pond Access is approximately 0.2 miles west of the Project boundary.

Horse Hill Nature Preserve: Horse Hill Nature Preserve is a 560-acre property owned by the town of Merrimack, located about three miles west of the Project Boundary. It is primarily a mixed hardwood forest, with a series of streams, ponds, swamps, and numerous wetlands. Old logging roads form the basis of what is today a trail network used by hikers, bikers, cross country skiing, snowshoeing, hunters, snowmobilers, and horseback riders. This trail network covers most of the property, however, there are still large areas without defined access.

Leslie Bockes Memorial Forest: Forest Society owns and manages this approximately 226-acre forest located in Londonderry, New Hampshire (five miles east of the Project boundary). Nearly four miles of old logging roads provide hiking, skiing, and snowshoeing with numerous access points. The trails are on well-maintained woods roads that enable easy walking and generally good footing. The tract is a known spot for bird and nature-watching (Forest Society 2020).

Twin Bridge Park: Twin Bridge Park is in Merrimack, New Hampshire, and features a baseball field, playground, picnic area, and extensive hiking trails through 27 acres of woods along Baboosic Brook (Town of Merrimack undated). Twin Bridge Park is approximately 0.2 miles west of the Project boundary.

New Hampshire Heritage Trail: The completed trail system will connect trail segments along the Lower Merrimack River and ultimately extend south into Massachusetts, and north along the Merrimack, Pemigewasset, and Connecticut Rivers to the Canadian border. Several trail sections have been completed along this part of the river and northward, with existing segments in Nashua, Hooksett and Manchester, New Hampshire (NHDES 2019a).

E.7.6.1.4 Recreation Opportunities in Massachusetts

The state of Massachusetts reports that recreation along the Project impoundment changes as open space generally decreases further downstream and riverfront communities are more industrialized (MEOEEA 2001). Water-based recreation (boating, fishing, canoeing, and swimming), is provided on the downstream portion of the Project impoundment by multiple boat ramps and waterfront parks. There are many additional recreational opportunities in and surrounding Lowell, including networks of trails, thousands of acres of nearby state forest, and urban passive parks for walking, jogging, dog-walking, and picnicking (City of Lowell 2018; MADCR 2014; Lowell National Historical Park [LNHP] 2017).

As part of the LNHP or Lowell Heritage State Park, different sites in and around the city of Lowell are related to the historical era of textile manufacturing and offer museum exhibits, walking tours, and interpretive/interactive displays (LNHP 2017; MADCR 2014). Boat tours led by NPS guides also provide access to the historic canal system and the Project impoundment. The canal boat tours highlight some of the Lowell Hydroelectric Project facilities by travelling through the historic navigation locks (NPS undated c). Although portions of the LHNP are within the Project boundary, it is not a FERC-approved recreation facility. Additional recreational opportunities provided by NPS at the LNHP include trolley rides available for touring the city.

The downstream portion of the Project impoundment is accessible for water-based recreation by the following recreational facilities:

Lowell National Historical Park: The LNHP was established in 1978 and is operated by the NPS. This National Historic Park is made up of a group of different sites in and around the city of Lowell, Massachusetts, related to the era of textile manufacturing that relied on hydroelectric power to operate during the Industrial Revolution of the early 1800s. It is a primary recreation attraction for the City of Lowell and the Lowell Hydroelectric Project. While the majority of the Project facilities, canals, gatehouses, dams, locks, and powerhouses, are necessary components of its operations, they serve a dual purpose as a NPS attraction for which it is maintained and preserved as a historic property (NPS undated c). As noted above, LHNP is not a FERC-approved recreation facility despite the canal system and many of the Project's facilities being located within the Project boundary.

Lowell Heritage State Park: The 83-acre Lowell Heritage State Park occupies a 2-mile long stretch along the north bank of the Project impoundment, upstream of the Pawtucket Dam. The park features historical exhibits that were created in partnership with the NPS to educate the public regarding the network of canals and mills constructed in the 19th century to power Lowell's then bustling textile industry. Activities available include biking, boating (non-motorized and motorized), canoeing and kayaking, swimming, fishing, hiking, and educational programs. Facilities include a paved bike path and walking esplanade, picnic area, a beach, restrooms, scenic viewing area, an outdoor concert stage, and visitors center (Commonwealth of Massachusetts 2018a). Also located within the park boundary is the University of Massachusetts Lowell Bellegarde Boathouse, which also houses the Merrimack River Rowing Association, a non-profit rowing club.

Rourke Brothers Boat Ramp (part of the Lowell Heritage State Park): The park provides a trailered boat launch, located on the north bank of the impoundment about 2 miles upstream of the Pawtucket Dam. Adjacent to the boat launch is an access dock for boating and fishing.

Chelmsford Boat Access: The park provides a trailered boat launch, shoreline fishing access, picnic areas, athletic fields, and trails.

In addition to the facilities mentioned above, these facilities are located within a 30-minute drive from the Project boundary:

Lowell-Dracut Tyngsborough State Forest: The Lowell-Dracut Tyngsborough State Forest is approximately one mile north of the Project boundary. The Lowell-Dracut Tyngsborough State Forest spreads across three towns and features over 1,140 acres of protected land, including 180 acres of open water or wetlands and 457 acres of land in the city of Lowell. Popular activities include hiking, fishing, hunting, cycling, birding, picnicking, nature walking, mountain biking, and playing various field sports. In the winter, people sled, ice skate, and cross-country ski (Commonwealth of Massachusetts 2018c).

Great Brook Farm State Park: Located seven miles south of the Project, this park is a working dairy farm connected to miles of trails that can be used for a variety of recreational activities. The park also includes historic buildings and resources, interpretive programming, and a cross-country ski concession.

Warren H. Manning State Forest: Located five miles south of the Project, this state forest is a largely wooded property with a small recreation area, complete with a spray deck, picnic area, water playground, and fitness trail.

Billerica State Forest: Located six miles south of the Project, this state forest offers rustic, multi-use trails and wooded areas for walking and wildlife viewing.

Carlisle State Forest: Located ten miles south of the Project, this state forest provides over a mile of trails through wooded property protected from forestry activities at the turn of the 20th century. The forest includes an older stand of exceptionally large eastern white pines.

Governor Thomas Dudley State Park: Located ten miles south of the Project, this 11-acre park is a small wooded parcel that provides access to the Concord River and links to other protected open spaces.

E.7.6.1.5 Existing Shoreline Management Plans

There is no formal Shoreline Management Plan or permitting policy for the shoreline of the Lowell Hydroelectric Project.

E.7.6.1.6 Existing Shoreline Buffer Zones

At normal pool elevation of 92.2 feet NGVD, there are approximately 32 shoreline miles bordering the current impoundment of the Pawtucket Dam. Both New Hampshire and Massachusetts have established shoreline buffer zones. Per New Hampshire's Comprehensive Shoreland Protection Act (CSPA), which contains minimum standards to protect public surface waters and their immediate environs, any disturbance activity greater than 50,000 $feet^2$ occurring within 250 feet of the Merrimack River requires an Alteration-of-Terrain permit (LMRLAC 2008). In Massachusetts, the Wetlands Protection Act (Massachusetts General Laws Chapter 131, Section 40) protects important water-related lands and other areas from destruction or alteration. Generally implemented by the local Conservation Commission in each municipality, the Act establishes a 100-foot buffer zone around all coastal banks, inland banks, freshwater wetlands, coastal wetlands, tidal flats, beaches, dunes, marshes, and swamps, and a riverfront area within 200 feet of rivers and streams (or 25 feet of some urban rivers) that flow year round. The canals in Lowell are specifically defined as not having a riverfront area [310 CMR 10.58 (2)1.g] (MACC undated).

E.7.6.1.7 National Wild and Scenic River System, National Trail System, and Wilderness Areas

The Merrimack River is not designated as a National Wild and Scenic River or under study for inclusion in the National Wild and Scenic River System. The Lowell Hydroelectric Project is not located within or adjacent to lands included in, or under study for inclusion in, the National Trails System or designated as, or under study for inclusion as, a Wilderness Area.

E.7.6.1.8 Nationwide Rivers Inventory

The upper portion of the impoundment was listed under the National Rivers Inventory in 1995. The full classified reach is 16 miles long from Amoskeag Dam in Manchester to the confluence with Pennichuck Brook in Merrimack. The reach is considered notable due to fish, historic, recreational, and wildlife values (NPS undated *b).*

E.7.6.1.9 State-protected Rivers

The lower reach of the Merrimack River, which includes the upstream impoundment of the Project in New Hampshire, is designated as a "Community River" under the New Hampshire Rivers Management and Protection Program (NHDES 2017). Community rivers are defined as "those rivers or river segments which flow through populated areas of the state and which possess actual or potential resource values. Such rivers have some residential or other building development near their shorelines, are readily accessible by road or railroad, and may include some impoundments or diversion." (NHDES 1990). The LMRLAC provides an advisory role on matters pertaining to the management of the river, and comments on development plans which might affect the river's resource values. The LMRLAC also maintains a river corridor management plan pursuant to NH RSA 483:10 (NHDES 2008).

E.7.6.1.10 Regionally or Nationally Significant Recreation Areas

The Lowell Hydroelectric Project is located within the LNHP, a regionally and nationally significant recreation area.

E.7.6.1.11 Recreation Use and Need

Pursuant to the approved study plan, Boott conducted a Recreation and Aesthetics Study to identify existing recreation use as well as recreation resources and activities that may be affected by the continued operation of the Project. The methods and results of the Recreation and Aesthetics Study are described in detail in Boott's Recreation and Aesthetics Study Report (HDR 2021a) filed with the Commission on February 25, 2021.

Field Inventory

Boott inventoried non-Project recreation facilities within the Project's vicinity in the fall of 2019, including the Chelmsford Boat Access, Depot Street Boat Ramp, Greeley Boat Ramp, Lowell Heritage State Park, LNHP, Merrill Park, Merrimack Trail System, Moore's Falls Conservation Area, NPS Canal Walkway, Pawtucket Falls Overlook, and Rourke Brothers Boat Ramp. The Visitor Center (the only-FERC approved recreation facility), was closed on the days of inventory, but the external features (e.g. parking lot) were also inventoried. Pursuant to the RSP, Boott collected information regarding each facility including the type and location of existing recreation facilities, the type of recreation provided (e.g., boat access, angler access, picnicking, etc.), existing amenities and sanitation, the type of vehicular access and parking (if any), the suitability of facilities to provide recreational opportunities and access for persons with disabilities (i.e., compliance with current Americans with Disabilities Act [ADA] standards for accessible design), GPS location data, and representative photographic documentation of recreation facilities. The results of the field inventory are presented in Appendix B to the Recreation and Aesthetics Study Report. A map of inventoried facilities is presented as Figure E.7-27.

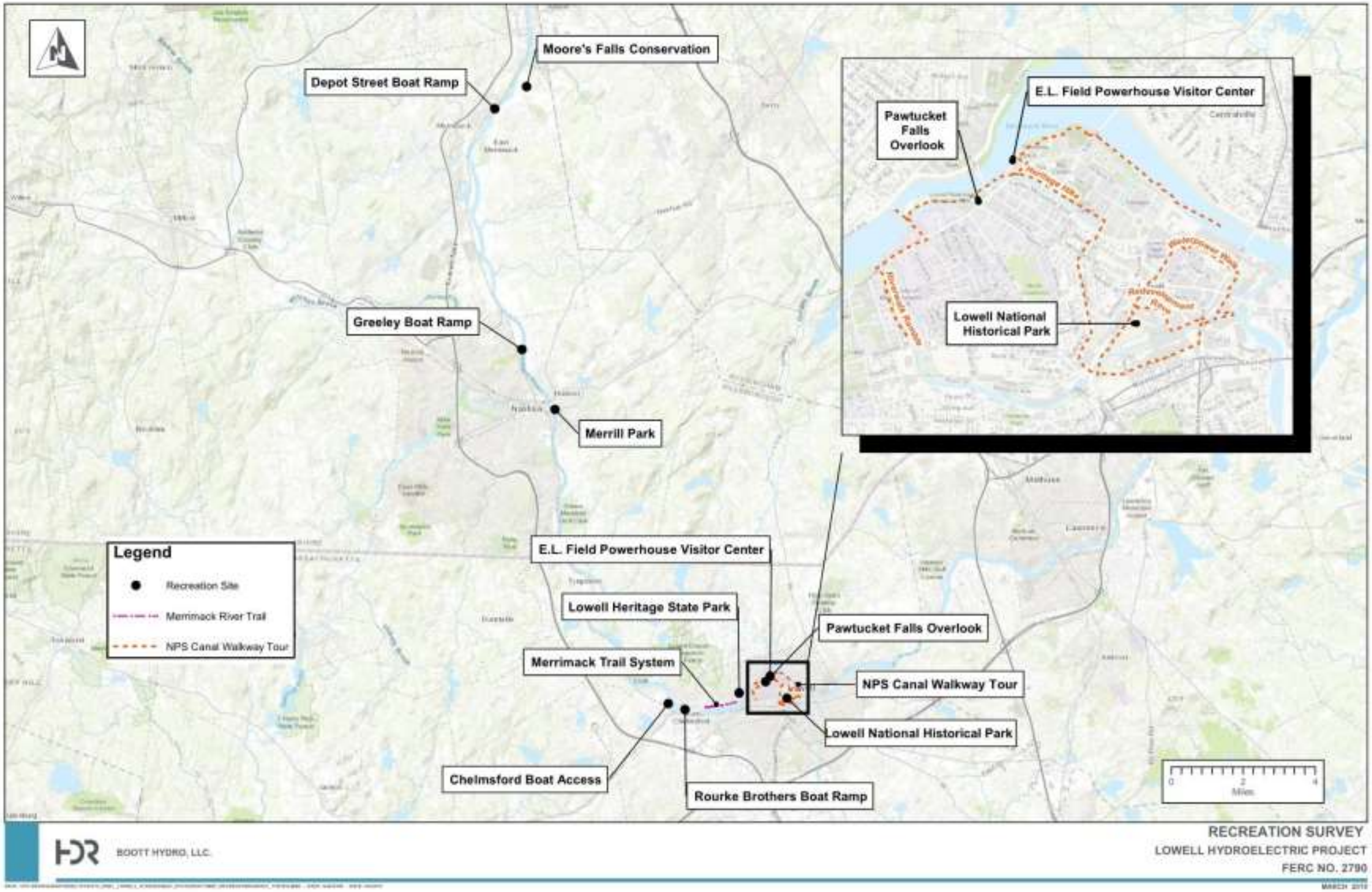
Visitor Use Data and Field Reconnaissance

As provided in the approved study plan, Boott conducted personal interviews (visitor intercept surveys) and field reconnaissance activities at recreation facilities in the Project's vicinity between May and October 2019. Boott developed survey questions based on general concepts and guidance from the U.S. Forest Service's (USFS) National Visitor Use Monitoring Handbook (USFS 2007) and questions that were asked during recreation studies for other relevant hydropower relicensings. The survey questions that were asked during the personal interviews are included in Appendix A of the Recreation and Aesthetics Study Report. Boott consulted with the NPS, MADCR, and American Whitewater (AW) to identify specific recreation survey locations.

In May 2019, Boott began conducting personal interviews at the Lowell Heritage State Park, Merrimack Trail System, Pawtucket Falls Overlook, NPS Canal Walkways, LNHP Visitor Center, Chelmsford Boat Access, Rourke Brothers Boat Ramp, Merrill Park, and Whitewater takeout location. The surveys were conducted on random weekdays and weekend days throughout the months of May, June, July, August, September, and

October of 2019. Personal interviews and field reconnaissance were conducted on four days of each month on both weekdays, weekend days, and holidays. A team of two technicians traveled between each of the aforementioned recreation sites and spent approximately one hour at each site conducting the personal interviews and collecting field reconnaissance data including (a) the various types of recreation activities, (b) an estimation of the number of vehicles, and (c) the approximate numbers of recreationists observed at each site. Field reconnaissance data is summarized in Appendix D of the Recreation and Aesthetics Study Report.

Figure E.7-27. Recreation Facilities Inventoried During Recreation and Aesthetics Study



For the personal interviews, individual recreationists and groups were interviewed, including visitors using boat launches and LNHP-managed facilities. Respondents answered questions verbally while a technician recorded their responses using the Qualtrics® offline survey platform to record and submit answers.[24] The personal interview questions included topics such as: general user information; age group, resident/visitor; purpose and duration of visit; distance traveled; history of visiting the site or area; types of recreational activities respondents participated in or planned to participate in during their visit; other recreational sites that respondents visited or intended to visit during their trip; general satisfaction with recreational opportunities, flow conditions, facilities, and the respondents overall visit and/or areas that need improvement; accessibility of facilities or areas; economic aspects, including dollars spent during their trip; and day use/overnight lodging during their visit. Before rotating to the next site, technicians also recorded the date, time, and weather conditions observed.

A total of 53 individuals participated in the interviews. Personal interviewees travelled an average of 7.3 miles to the recreation area, with a range of 0.1 miles to 3,000 miles. The majority (77 percent) of personal interview respondents rated their overall experience of recreational activities at the Project as "totally acceptable" or "acceptable." Results from the personal interviews are compiled in Appendix C of the Recreation and Aesthetics Study Report.

Online Survey

In addition to the personal interviews and visitor use data collection, Boott developed a version of the interview questions to allow respondents to provide survey responses online. In accordance with the approved study plan, the survey was made available for one year, from June 2019 to June 2020, on the Project's relicensing website (www.lowellprojectrelicensing.com). The online survey was developed using the Qualtrics® survey platform. Boott posted a brief description of the purpose and intent of the survey and the website address at popular recreation access areas at the Project. During personal interviews and field reconnaissance, Boott provided handouts to recreationists with the relevant information on how to access the online survey. Boott notified the Commission and stakeholders of the availability of the online survey in the Second Quarterly Study Progress Report filed with the Commission on October 1, 2019. The survey questions developed for the online survey are also included in Appendix A of the Recreation and Aesthetics Study Report.

A total of 96 respondents completed the online survey. Online respondents stated they travelled on average around 11 miles to the Project area. The majority (92 percent) of online respondents rated their overall experience of recreational activities at the Project as "totally acceptable" or "acceptable." Results from the online surveys are compiled in Appendix E of the Recreation and Aesthetics Study Report.

[24] While the survey questions in the approved study plan were utilized for these interviews, the numbering and specific wording was adapted during the interview to better facilitate the interview and to accommodate the Qualtrics® survey platform.

E.7.6.1.12 Evaluation of Water Levels and Flows on Recreational Access

In accordance with the SPD, Boott initiated data collection to better understand effects of the crest gate and water levels and flows on (1) NPS boat tours and (2) access to the Northern Canal Walkway. These methods and results are described in detail in Boott's final Recreation and Aesthetics Study Report filed with the Commission on February 25, 2021.

NPS Boat Tours

Under the amended Crest Gate System Operations Plan, when flows in the river are below 8,600 cfs [the combined hydraulic capacity of the E.L. Field Powerhouse (6,600 cfs) and downtown canal system (2,000 cfs)], the reservoir elevation is maintained at the normal pond elevation of 92.2 ft NGVD 29. When Merrimack River flows exceed 8,600 cfs, the Crest Gate System Operations Plan allows for a gradual rise in elevation to ± 93.2 ft NGVD 29 as flows reach approximately 11,850 cfs. With this 1-foot elevation rise of the Project impoundment, NPS states their boats would be unable to pass under the Pawtucket Street Bridge.

The Project maintains a normal pond elevation of 92.2 ft NGVD 29 when flows in the Merrimack River are up to 8,600 cfs. According to USGS gage data presented in Table E.7-1, average flows during the operating season (May 15 through October 15) for NPS boat tours generally do not exceed 8,600 cfs. May is the only month with an average Merrimack River flow above 8,600 cfs.

As described above, when Merrimack River flows exceed 8,600 cfs, the crest elevation gradually rises to 93.2 ft NGVD 29 until flows reach 11,850 cfs. Ultimately, only between Merrimack River flows of 11,850 cfs and 12,500 cfs (NPS' self-reported threshold), are NPS boats supposedly unable to pass under Pawtucket Street Bridge. This is a relatively narrow window, especially since the average flow for the entire operating season never reaches 11,850 cfs, and a 10% chance of exceedance of 11,850 cfs only occurs in May, June, and October.

Additionally, while Boott is permitted by the Crest Gate Operations Plan to raise the impoundment level to 93.2 ft, it is not Boott's standard practice to do so every time flows reach 11,850 cfs. As detailed in the Water Level and Flow Effects on Historic Resources Study, Boott collected impoundment elevation data from March 10 – September 29, 2020, and the results are shown below in Figure E.7-39. As shown, there were only slight exceedances above the normal pond elevation during the months of March and April, despite the highest monthly average flows occurring during the months of March (11,484 cfs) and April (17, 901 cfs).

The majority of flows through the Lowell Project are a direct result of the annual hydrologic cycle, much of which is unpredictable and inconsistent. The effect of the crest gate system on NPS boat tours appears to be minimal. Merrimack River flows high enough to raise the pond elevation 1-foot are seemingly just as likely to rise above NPS' self-reported threshold of 12,500 cfs.

Northern Canal Walkway

The Northern Canal Walkway opens seasonally (May 15 through October 15) when flow rates in the Merrimack River and Northern Canal are lower than 3,500 cfs. This threshold was determined in a study demonstrating that a surge wave above 3,500 cfs in the Northern Canal poses a risk of overtopping the Great River Wall. In 1999, the Licensee completed construction of the Surge Gate, designed to attenuate the surge wave in the canal that occurs during sudden plant shutdown. A test of the Surge Gate revealed that the gate did attenuate the resulting transient wave. However, as reported to FERC, the test indicated when fully opened, the significant volume of discharge through the Surge Gate is hazardous to any persons in the riverbed below or near the gate. FERC directed Boott to design a Public Safety Plan to warn the public of this hazard, which included warning signs, sirens and beacons installed at various locations along and in the Merrimack River (FERC 2000). Accordingly, to be conservative and assure public safety, the 3,500 cfs threshold to open the Northern Canal Walkway remained despite the installation of the Surge Gate.

Within one year of license issuance, Boott will develop a Recreation Access and Facilities Management Plan in consultation with the stakeholders to: a) evaluate opportunities for increasing pedestrian access to the Northern Canal Walkway under certain conditions; b) define flow management practices needed to enhance recreational opportunity in the project vicinity; and c) continue to manage the Project's recreation facility, the E.L. Field Powerhouse Visitor Center.

E.7.6.1.13 Land Use

Land use in the immediate vicinity of the Project is shown in Figure E.7-28 through Figure E.7-29. There are limited Project lands within the Project Boundary and only facilities needed for operation of the Project are included within the Project Boundary. Land use at the Project facilities is primarily Developed, High Intensity.

Land use along the impoundment of the Lowell Hydroelectric Project varies. The land use at the southern reach of the impoundment, in the Nashua area, and near Manchester is predominantly Developed, High Intensity. Elsewhere along the impoundment, where there are suburban and rural areas, land use is predominantly Developed, Low Intensity, except at the northern reach of the impoundment where other significant land uses include forest, hay/pasture, and crops.

Figure E.7-28. Land Use in the Vicinity of the Lowell Hydroelectric Project and Proposed Project Boundary

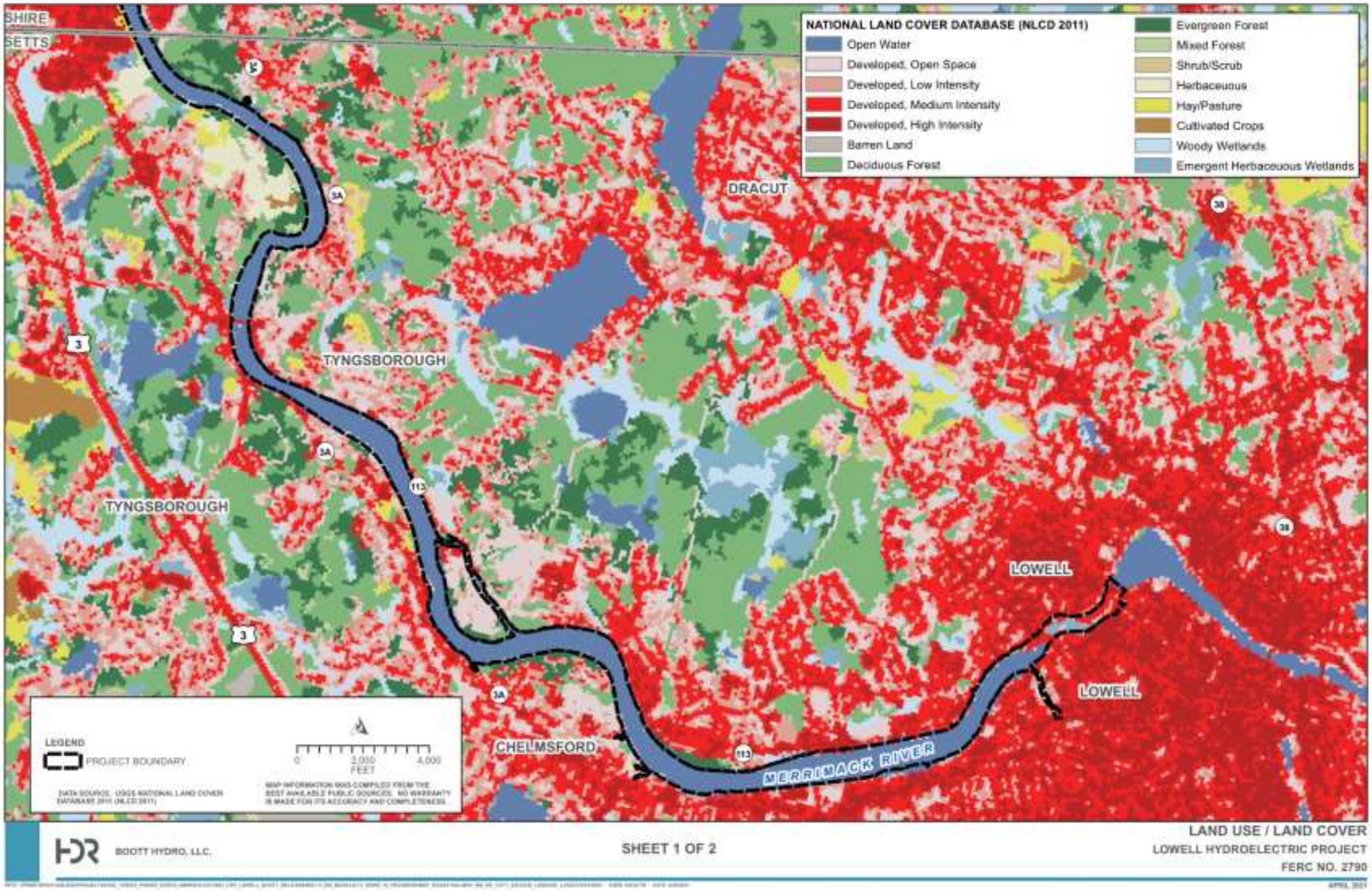
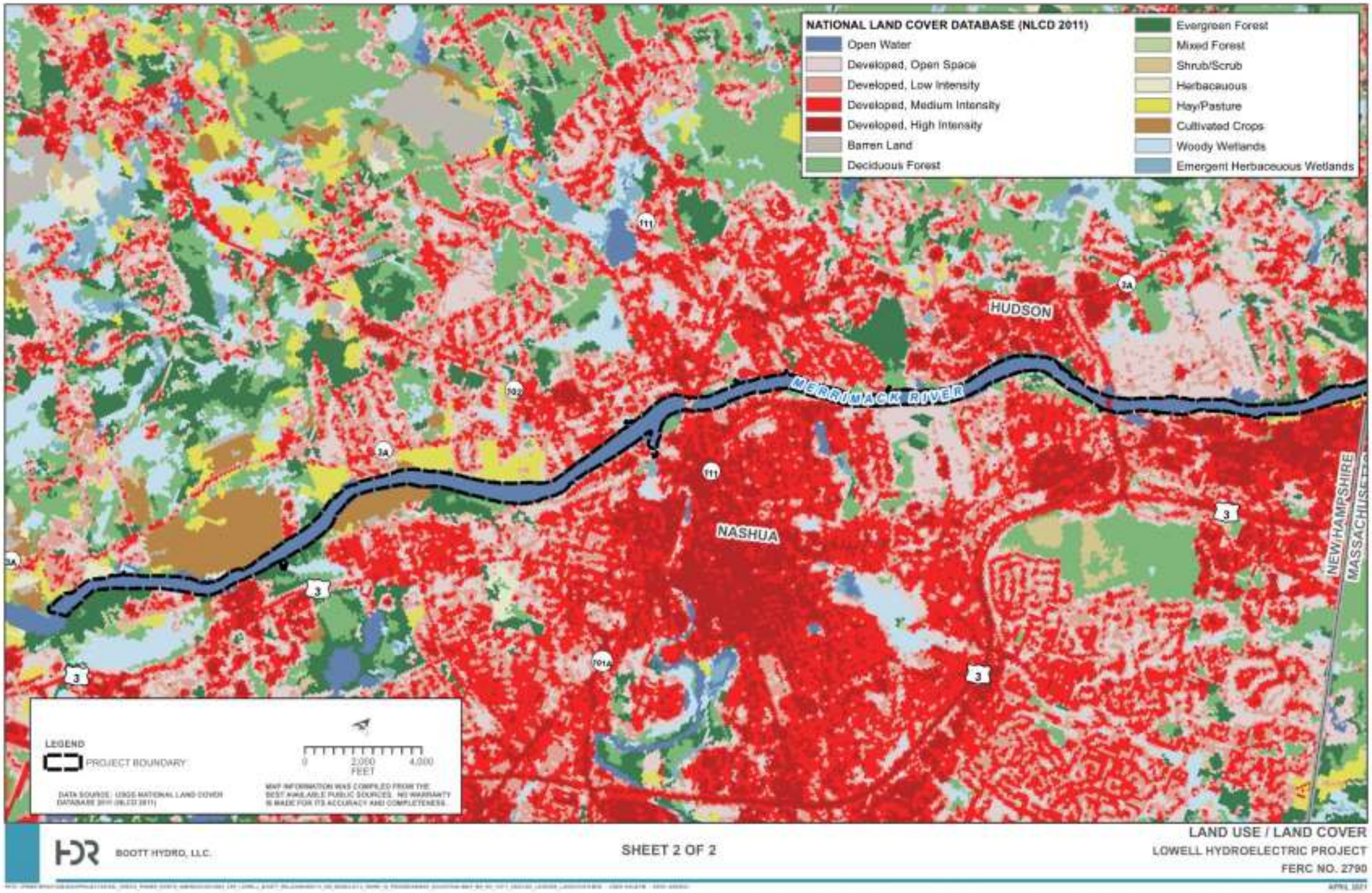


Figure E.7-29. Land Use in the Vicinity of the Lowell Hydroelectric Project and Proposed Project Boundary



E.7.6.2 Environmental Analysis

FERC's SD2 identified effects of continued Project operations on recreation and land use as potential resource issues. Specifically, SD2 identified the following potential resource issues related to recreational use and land use to be analyzed for site-specific effects:

- Effects of continued project operation on recreational use in the Project area, including the adequacy of existing recreational access, and the adequacy and capacity of existing recreational facilities.
- Effects of continued project operation on land use in the project area.

E.7.6.2.1 Recreational Resources

As described in the Recreation and Aesthetics Report (HDR 2021a), more than 145 recreationists participated in interview or online surveys to share their opinions of and experiences with existing non-Project recreation facilities within the Project's vicinity. Most sites inventoried were reported in good condition, with parking lots, ample signage, and educational exhibits. Respondents both in-person and online overwhelmingly rated their overall experience as "totally acceptable" or "acceptable". Overall, the visitor use data indicates that non-Project recreation facilities within the Project's vicinity provide an "acceptable" or "totally acceptable" recreation experience for visitors.

While walking was the most common primary recreation activity, other trail-related activities (dog-walking, hiking, running, or jogging), bank and/or boat fishing, and kayaking all ranked high among activities that respondents participated in while visiting Project recreation facilities. The most frequently visited recreational facilities in the Project area were Lowell Heritage State Park, the Rourke Brothers Boat Ramp, Chelmsford Boat Access, Merrimack Trail System, and LNHP-facilities. Potential issues with the recreation facilities included crowding and safety; however, in general, respondents did not experience much crowding at the recreational facilities, parking issues, or lack of accessibility to the specific recreational facilities.

As part of the Recreation and Aesthetics Study, Boott conducted an evaluation of expanded recreational access in the Project canals. Boott's primary concerns were the recreational rights to the canal system and understanding public safety issues associated with providing recreational access in the Project's canal system. Boott reviewed many sources to understand the recreational rights to the Lowell canal system, including the Memorandum of Understanding (MOU), the 1984 Great Deed between Proprietors and Boott (Proprietors 1984), the 1986 Order of Taking (Commonwealth of Massachusetts 1986), and the 1995 Grant of Easement from the Commonwealth of Massachusetts to the LNHP (Commonwealth 1995).

By letter dated May 14, 1980, MADCR stated that they were currently in the process of negotiating purchase rights to the Lowell canal system which would allow for recreational boating in the canals, stating further that use of the canals and implementation of the boating program were key elements of the Lowell Heritage State Park (Massachusetts Department of Emergency Management [MADEM] 1980). Through the 1986 Order of Taking, MADCR purchased all air rights over the canals, including over the canal walls and dams, and the exclusive right to use water in the entire canal system for recreational, educational, and navigational purposes, unless said purposes interfere with Boott's hydroelectric generation (Commonwealth 1986). Included in the 1986 Order of Taking is a permanent and exclusive easement to MADCR for all canal walls, beds, or bottoms throughout the canal system for purposes consistent with the use of the canal system as a recreational park. These purposes specifically include placement and attachment of docks, wharves, walls, and boat ramps of a temporary or permanent nature (Commonwealth 1986). The 1995 Grant of Easement from MADCR to LNHP did not convey these exclusive recreation rights to LNHP (Commonwealth 1995).

Based on the review of the MOU, the 1984 Great Deed between Proprietors and Boott, the 1986 Order of Taking, and the 1995 Grant of Easement from the Commonwealth of Massachusetts to the LNHP, Boott currently does not have any right to expand recreational opportunities throughout the Lowell canal system. MADCR purchased all recreational rights over all the canals and canal walls (even canals owned by Boott), including exclusive navigational rights such as boating or canoeing. MADCR maintains an exclusive and permanent easement throughout the entire canal system to install access points such as boat ramps, wharves, and docks. Boott and other stakeholders are not permitted to use the canals as recreational resources, as those rights are exclusively held by MADCR.

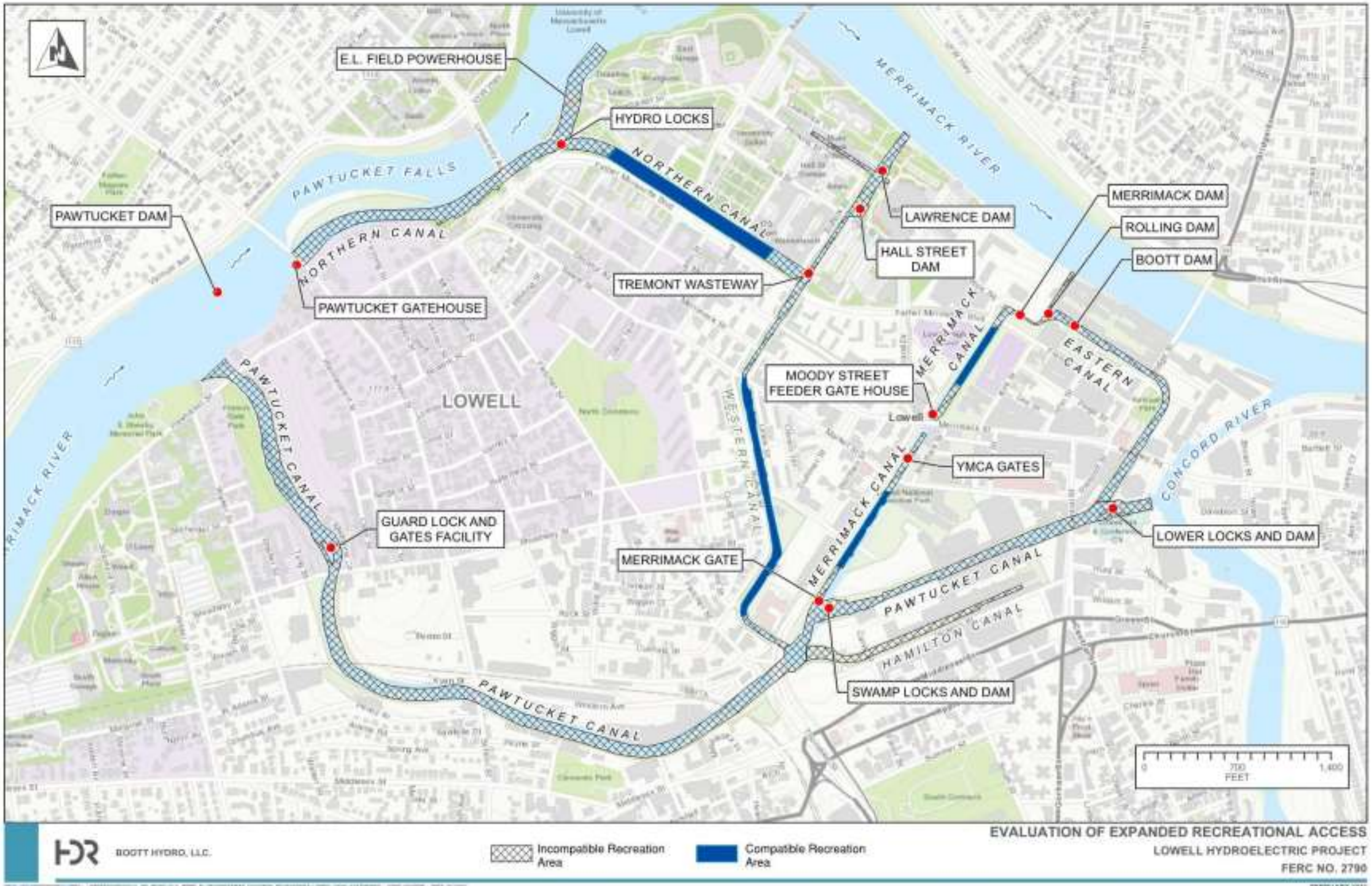
Additionally, while Boott does not have recreational or navigational rights to the canal system, Boott believes that providing access for the general public to the Northern Canal between the Pawtucket Gatehouse and the E.L. Field powerhouse would present a number of significant safety concerns. The current velocities in the Northern Canal are too high for safe navigation by non-powered boats when the E.L. Field powerhouse is operating, and the steep canal walls restrict the ability of public safety officials to respond to any emergency situations. Allowing recreationists access to or near to these Project facilities poses significant and unacceptable safety and security risks. That said, Boott is willing to work with local stakeholders to manage canal flows and water levels to facilitate safe public access to certain areas of the non-Project canal system identified below in Figure E.7-30, should that be desired.

As reported in the Recreation and Aesthetics Study Report, Boott conducted an analysis of any effects of the crest gate and water levels and flows on NPS bout tours and access to the Northern Canal Walkway. The effect of the crest gate system on NPS boat tours appears to be minimal, as flows in the Merrimack River are generally not that high (8,600 cfs) during the boat tour season, and even under those flow conditions Boott does not always raise the crest gates.

Boott's surge gate operations have the potential to affect access to the Northern Canal Walkway. Due to safety reasons with the surge gate, the Northern Canal Walkway opens seasonally (May 15 through October 15) when flow rates in the Merrimack River and Northern Canal are lower than 3,500 cfs.

Continued Project operations as proposed by the Licensee are not expected to result in any changes to the adequacy, availability, and accessibility of the non-Project related recreational facilities within the Project's vicinity.

Figure E.7-30. Identified Recreation Areas Potentially Compatible with Project Operations



E.7.6.2.2 Land Use

The facilities of the Lowell Hydroelectric Project are situated in an intensely developed urban landscape. The historic use of the Merrimack River in the vicinity of the Project for navigation, transportation, and industrial applications remain as the primary feature guiding its current use as a tourism attraction, municipal and industrial infrastructure element, and recreational asset. The City of Lowell was built by hydropower during the Industrial Revolution and hydropower is consistent with the current land use as an urban, industrial city. Continued Project operations as proposed by the Licensee are not expected to result in any changes to land use.

E.7.6.3 Proposed Environmental Measures

Boott proposes continued operation of the Project with certain measures consistent with those required by the Project's existing license.

Within one year of license issuance, Boott will develop a Recreation Access and Facilities Management Plan in consultation with the stakeholders to: a) evaluate opportunities for increasing pedestrian access to the Northern Canal Walkway under certain conditions; b) define flow management practices needed to enhance recreational opportunity in the project vicinity; and c) continue to manage the Project's recreation facility, the E.L. Field Powerhouse Visitor Center.

E.7.6.4 Unavoidable Adverse Impacts

Continued Project operations as proposed by the Licensee are not expected to result in any changes to recreation or land use. Considering that the Whitewater Boating and Access Study is on-going, Boott anticipates continuing to consult with AW and other relevant stakeholders on appropriate PM&E measures, if any, based on the results of that study. As appropriate, Boott may propose additional PM&E measures in a supplement to this license application.

E.7.7 Aesthetics and Socioeconomic Resources

The subsections below describe aesthetic and socioeconomic resources in the vicinity of the Project and consider the effects of continued operation of the Project as proposed by the Licensee on these resources. Descriptions of the affected environment, the environmental analysis, the proposed environmental measures, and the identification of unavoidable adverse effects were developed based on available data presented in the Licensee's PAD, other existing information, and from the results of the Recreation and Aesthetics Study performed by Boott in 2020.

E.7.7.1 Affected Environment

E.7.7.1.1 Aesthetic Resources

The Lowell Project is located within the Seaboard Lowlands Section of the New England Physiographic Province. The Taconic, Green, and White Mountain ranges are distinct features of the New England Physiographic Province. The Seaboard Lowlands Section is lower in elevation and less hilly than the adjoining New England Upland Section (Flanagan et al. 1999). The local relief in the Merrimack River Valley in the Project vicinity is generally characterized as low, open hills. The Merrimack River watershed encompasses approximately 5,010 square miles within the states of New Hampshire and Massachusetts. It is the fourth largest watershed in New England. Although the Merrimack River watershed is heavily forested (75 percent of the land area is covered with forest), it also supports all or parts of approximately 200 communities with a total population of 2.6 million people (USEPA 2020b; USACE 2006).

Along the upper northern boundary of the Merrimack River watershed, the relatively undeveloped White Mountain National Forest in New Hampshire provides almost 800,000 acres of protected land; this region also provides over one million acres of private forest and agricultural land (NHDNCR 2018). The Project dam is located at RM 41 on the Merrimack River, and the impoundment extends upstream approximately 23 miles almost to the City of Manchester in New Hampshire. The Project impoundment is characterized by the urban/industrialized cities of Nashua, New Hampshire and Lowell, Massachusetts. In the vicinity of the Project in Lowell, Massachusetts, the Merrimack River flows through a region of rapid population growth and development stemming from the 1800s that is still heavily influenced by the growing Boston urban metropolitan area (Figure E.7-28 through Figure E.7-29).

The Project facilities are generally bordered to the north by Route 113 and VFW Highway, and to the south by Pawtucket Street in the heavily populated City of Lowell, MA. The Project's impoundment is largely visible from Route 113 to the north and east and from Route 3A (Tyngsboro Road) to the south and west. One of the best views of the dam is from the Pawtucket Gatehouse which is located at the southern abutment of the Pawtucket Dam that controls flow into the Northern Canal. The Project's facilities can also be seen from the pedestrian trail located along the Northern Canal, from the University Avenue Bridge crossing, and from VFW Highway. The Project's bypass reach, located north of Mammoth Road and extending down below the Project's powerhouse, offers scenes of jumbles of rocks near the Pawtucket Dam, bedrock outcroppings, and ledges at low water periods, and contains strips of forest vegetation along the streambanks typical of the region. Scenic intrusions and topographical alterations resulting from original Project construction have long since disappeared, and the Project area has become integrated with the environmental and visual setting of the surrounding area.

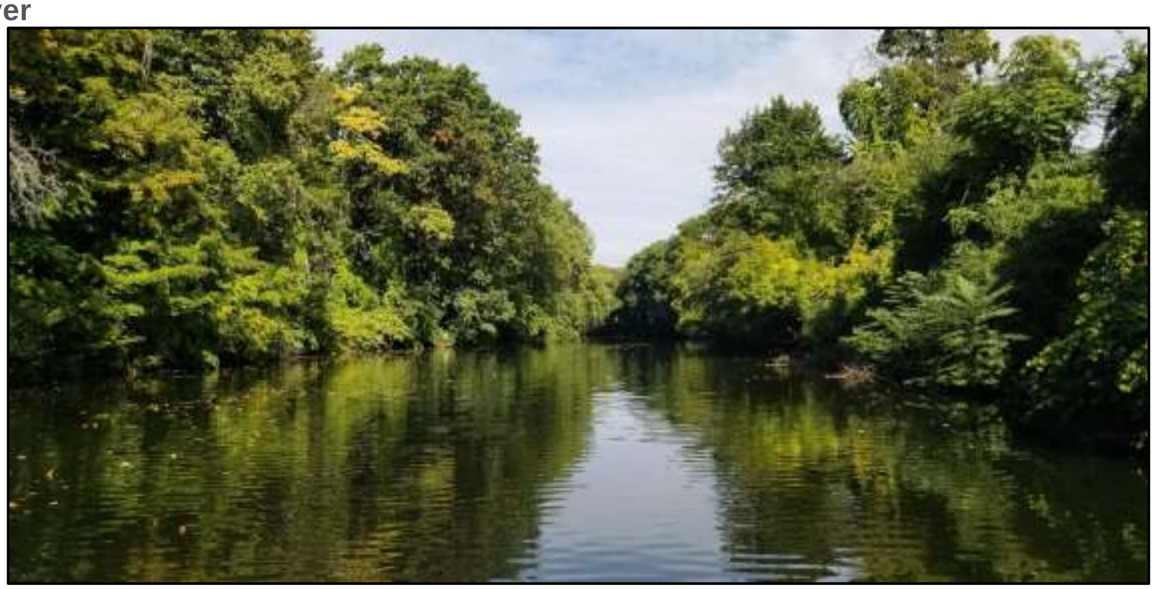
The aesthetic resources of the Lowell Project largely reside in the historic infrastructure that the Project is a part of. The multiple historic textile mills, gatehouses, locks, canals, and walkways that are part of the Lowell National Historical Park are the primary aesthetic attraction of the Lowell Project (Figure E.7-31 through Figure E.7-35). Tourists are drawn to the city of Lowell to witness the historic site of the Industrial Revolution in the United States. Lowell is essentially a living exhibit of the process and the consequences of the American Industrial Revolution. In addition, the Project's immediate shoreline, associated canals, and river corridor offer a scenic backdrop in an intensely urbanized setting (Figure E.7-33 and Figure E.7-34).

Figure E.7-31. Pedestrian Walk with View of the Northern Canal (left) and Bypass Reach (right).

Figure E.7-32. Guard Lock and Gates Facility.

Figure E.7-33. Upstream View of Bypass Reach Near University Avenue

Figure E.7-34. Westerly View of Pawtucket Canal Near the Confluence with the Merrimack River



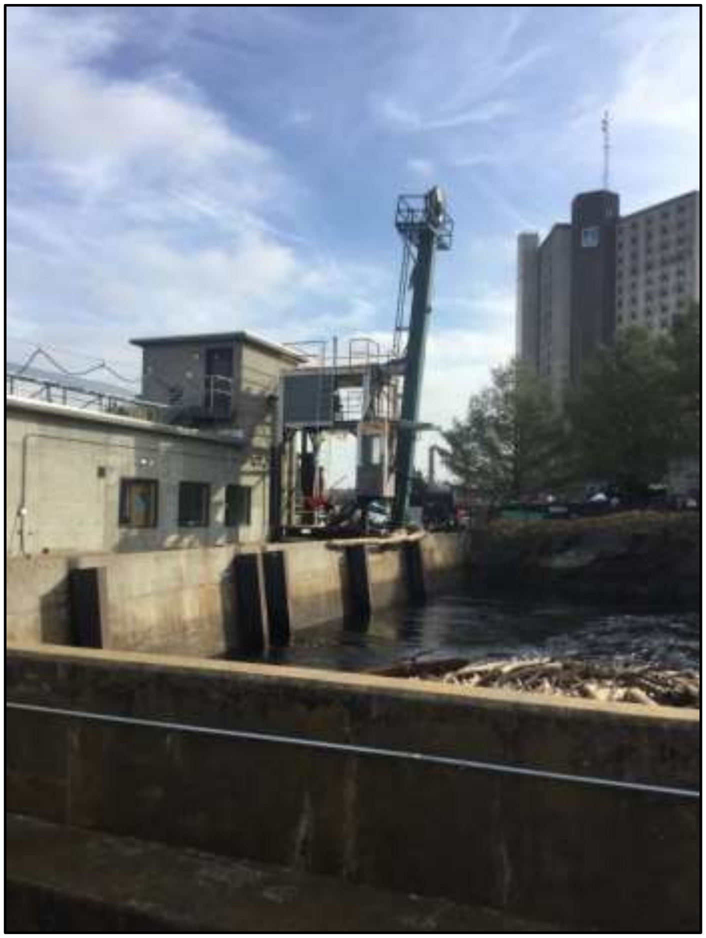
During the original licensing of the Project, NPS and other stakeholders stated that the powerhouse architecture should not mimic the nineteenth-century structures nearby. It was stated by officials that the modern nature of the new facility would be apparent and that it would harmonize well with the Northern Canal, the local neighborhood, and the river. The Licensee agreed to coordinate final exterior building design with the NPS and other interested agencies to help achieve this aim. Landscaping of the powerhouse area was also discussed in the prior application and the following proposals were made (Boott Mills 1980):

- Riverbank vegetation near the site to be protected to the extent feasible.
- Steep, riverside areas disturbed during construction are to be planted with native plant material.
- Street-level areas to compliment state and federal park design.
- Transmission lines from station to adjacent highway bridge to be inconspicuous.

Figure E.7-35 and Figure E.7-36 depict the Pawtucket Dam and E.L. Field Powerhouse, respectively. The E.L. Field Powerhouse is located in the vicinity of more modern architecture such as the University of Massachusetts Lowell dormitories.

Figure E.7-35. Westerly View of Pawtucket Dam from the Pawtucket Gatehouse

Figure E.7-36. E.L. Field Powerhouse with University of Massachusetts Lowell in the Background



E.7.7.1.2 Recreation and Aesthetics Study

Pursuant to the RSP, on April 9, 2020, Boott mapped areas within the canal system owned or under the control of Boott where waterborne trash may be a potential concern. The amount and type of waterborne trash that accumulates within the Project boundary can vary according to several factors including the season, Project operations, and the magnitude and duration of the flow events (HDR 2021a).

The surveys for waterborne trash have shown that waterborne trash accumulates within the Project's canal system, and these accumulations are somewhat dependent on the level of the water within the canals as well as the required operation of some of the NPS gates within the study area. For example, NPS gates that are operated on a routine basis had minimal signs of waterborne trash associated with them, while others that are largely in the closed position tended to have accumulations of waterborne trash behind them at varying densities (HDR 2021a).

Accumulated waterborne trash includes material floating on the impoundment surface and/or found on the surface of the canal system. Most of the waterborne trash accumulation within the Lowell Canal system appears to be derived from upstream inputs (the Merrimack River) as well as direct canal inputs (accidental and intentional littering) and from runoff events (also likely from accidental and intentional littering) (HDR 2021a).

In total, eight (8) areas of waterborne trash totaling 0.21 acres were mapped on April 9, 2020 as well as three additional areas of accumulated trash on the canal bed and a single area with a waterborne sheen. The total study area encompassed approximately 44 acres and the mapped areas within the canals were 3.531 acres or approximately 154,000 square feet (HDR 2021a).

Waterborne trash consisted of common materials such as foam board pieces, plastic cups, foam plates, foam bait containers, shoes, plastic bottles, organic debris, etc. (see Figure E.7-37 and Figure E.7-38).

Figure E.7-37. Waterborne trash on the Pawtucket Canal at Guard Lock and Gates Facility.

Figure E.7-38. Waterborne trash on the Merrimack River upstream of the Northern Canal Gatehouse

E.7.7.1.3 Socioeconomic Resources

The Lowell Project is located in Middlesex County, Massachusetts and Hillsborough County, New Hampshire. The population of Middlesex County, based on the vintage year[25] V2019 census data, was 1,611,699 resulting in a 7.2 percent increase in population from April 1, 2010 to July 1, 2019 (U.S. Census Bureau undated). The population of Hillsborough County, based on the vintage year V2019 census data, was 417,025 resulting in a 4.1 percent increase in population from April 1, 2010 to July 1, 2019 (U.S. Census Bureau undated).

According to the U.S. Census Bureau, the median household income in Middlesex County (in 2018 dollars) from 2014-2018 is estimated to be $97,012. There is an estimated 7.3 percent[26] living below the poverty line in Middlesex County (U.S. Census Bureau undated). The most common employment sectors for Middlesex County are healthcare and social assistance; professional, scientific, and tech services; and educational services (Data USA undated).

According to the U.S. Census Bureau, the median household income in Hillsborough County (in 2018 dollars) from 2014-2018 is estimated to be $78,655. There is an estimated 7.4 percent[2] living below the poverty line in Hillsborough County (U.S. Census Bureau undated). The most common employment sectors for Hillsborough County are healthcare and social assistance, manufacturing, and retail trade (Data USA undated).

The Lowell Project is located within the Greater Boston metropolitan area, which is primarily composed of urban and suburban towns and cities. The city of Lowell's estimated population in 2019 was 110,997 - making it the fourth largest city in Massachusetts. The population of Lowell grew an estimated 4.2 percent since the previous 2010 census. The median household income in Middlesex County (in 2018 dollars) from 2014-2018 is estimated to be $97,012, while the Lowell household annual income (in 2018 dollars) from 2014-2018 was $51,987. An estimated 20.7[2] percent of families were below the poverty line in 2018 (U.S. Census Bureau undated).

The economy of Lowell employs approximately 50,000 people. Lowell's economy is specialized in manufacturing, administration, waste management services, and healthcare and social assistance. The largest industries in Lowell are healthcare, manufacturing, and retail trade. Educational, scientific, and technical services are also notable contributing industries to the Lowell economy.

The City of Lowell's Healthy and Sustainable Local Economy 2025 Master Plan targets multiple facets of the local economy and the well-being of its citizens. One facet is to continue to support the urban revitalization plan of the Hamilton Canal District which includes properties adjacent to Lowell Project facilities. A second facet of the City of Lowell's plan is to attract and maintain environmentally sustainable businesses,

[25] The vintage year (e.g., V2019) refers to the final year of the series (2010 thru 2019). Different vintage years of estimates are not comparable.

[26] Estimates are not comparable to other geographic levels due to methodology differences that may exist between different data sources.

institutions, and industry. Hydropower is a suitable industrial energy supplier that satisfies this local economic development goal (City of Lowell 2013).

E.7.7.2 Environmental Analysis

FERC's SD2 identified the following potential resource issue related to aesthetics and socioeconomic effects:

- Effects of continued project operation on aesthetic resources in the project area, including the historic industrial context of the project structures and features.

E.7.7.2.1 Aesthetic Resources

A described above, the facilities of the Lowell Hydroelectric Project are situated in an intensely developed urban landscape. The Project dam is located at river mile 41 on the Merrimack River, and the impoundment extends upstream approximately 23 miles almost to the City of Manchester in New Hampshire. The Project impoundment is characterized by the urban/industrialized cities of Nashua, New Hampshire and Lowell, Massachusetts. In the vicinity of the Project in Lowell, Massachusetts, the Merrimack River flows through a region of rapid population growth and development stemming from the 1800s that is still heavily influenced by the growing Boston urban metropolitan area.

The aesthetic resources of the Lowell Project largely reside in the historic infrastructure of the Project. The multiple historic textile mills, gatehouses, locks, canals, and walkways that are part of the Lowell National Historical Park are the primary aesthetic attraction of the City of Lowell, portions of which are included in the Lowell Project (Figure E.7-31 through Figure E.7-35).

Pursuant to the approved study plan for the Recreation and Aesthetics Study, Boott reviewed several sources to summarize historical and current practices for maintaining aesthetics (vegetation and waterborne trash management) in the Project Area. Following establishment of the LNHP in 1978, MADCR[27], NPS, and Proprietors, entered into an agreement in 1979 regarding management of the Lowell canal system and other historic structures. This agreement establishes MADCR as the lead party responsible for the maintenance of canal structural components, including canal banks and walls. As the lead party, MADCR was responsible for "landscaping and damage repair" to canal banks and walls, with assistance provided by NPS if needed. NPS was charged with the operation of the canal-related exhibits and services, and Proprietors were responsible for the operation and maintenance of the hydroelectric and hydromechanical parts of the Lowell canal system (NPS 1981). NPS developed and issued a Final General Management Plan (FGMP) in August 1981 to provide a basis for visitor use, resource management, and general development within the LNHP. The FGMP states that management of the Lowell canal system will be accomplished through cooperative agreements between private and public entities, but MADCR is the lead agency

[27] The signatory of the 1979 agreement was the Massachusetts Department of Environmental Management, the predecessor agency to MADCR.

responsible for maintaining, developing, and renovating the major elements of the canal system (NPS 1981).

In 1991, MADCR, the NPS, and Boott executed a MOU for the purpose of maintaining and operating the Lowell Canal System.[28] The MOU assigned specific responsibilities to each party and was filed with the Commission[29] on April 25, 1991 (MOU 1991). Article IV of the MOU directed NPS to assist MADCR in the removal and control of vegetation along the canal system, ("particularly that growing on and in the canal walls") and to assist MADCR in performing ground maintenance. Article IV also directed NPS to assist MADCR in the removal of litter and other waterborne trash from the Lowell Canal System, and states NPS is solely responsible for maintaining and cleaning, ("including removal of trash") all existing trash booms and safety lines/booms on the Lowell Canal System (MOU 1991).

Responsibilities assigned to MADCR under Article V of the MOU include serving as the lead agency for all grounds maintenance, keeping all grass, trees, and shrubs neatly trimmed and in a healthy condition, removing dead or diseased plants, fertilizing, pruning, and thinning of plants (as required), and approving ground maintenance or improvement plans as proposed by NPS. Article V also directs MADCR to assist NPS in the removal and control of destructive vegetation along the canal system, and to cooperate with the NPS on developing a litter removal program for waterborne litter and trash on the canals. (MOU 1991). This article also directed MADCR to reimburse NPS for time and materials for work done on the canal system.

Article VI of the MOU directed NPS and MADCR to hold a joint annual meeting to develop an annual destructive vegetation clearing program and canal surface water cleanup program. The annual programs were to be developed in accordance with each agency's budget and seasonal staffing level. Under Article VI, MADCR was also directed to consult with NPS to develop a long-term capital improvement program for the canal system. The minutes of this annual meeting between MADCR and NPS were to be provided to Boott and the Proprietors each year (MOU 1991).

Article IX stated that the MOU would expire five years from the date of signing, with an option for renewal. Efforts to renew the MOU apparently stalled around 1996, as MADCR issued a Grant of Easement[30] to the NPS in late 1995 (FERC 2001; Boott 2001; Lowell Sun 2006). This Grant of Easement provided NPS rights to implement construction and maintenance improvements at forty-two MADCR-owned parcels around the canal system. Such rights include landscaping, decking, and lighting. The Grant of Easement did not exclusively limit NPS's rights, only stating that construction and maintenance improvements must be consistent with the use of the area as a park. The Grant of Easement did not relinquish MADCR's waterborne trash and vegetation management responsibilities provided by the FGMP or MOU, as described above.

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[28] Proprietors of the Locks and Canals on the Merrimack River was included as a party in the MOU but did not execute the agreement.

[29] The 1991 Memorandum of Understanding is available on FERC's eLibrary (https://elibrary.ferc.gov/eLibrary/search) under docket number p-2790.

[30] The 1995 Grant of Easement is also generally referred to as LNHP Deed No. 40.

In the Resource Management Plan (RMP) for the Lowell/Great Brook Planning Unit, MADCR elaborates the agency was directed by the Commonwealth in 1993 to "concentrate on maximizing the riverfront component and minimizing, but not eliminating, [its] position in the downtown." Under a lower annual budget, MADCR states it has since focused its resources on the riverfront portion of the Lowell Heritage State Park system and less on the downtown canal system (MADCR 2014).

Boott annually removes accumulated river-borne debris from the upstream side of the Northern Canal Gatehouse under an MADCR permit. This effort is performed as necessary, typically two to three times annually. Boott also removes debris that accumulates from the upstream side of the Guard Locks and Gatehouse in the Pawtucket Canal on an as necessary basis, both for aesthetics and to ensure that debris does not interfere with the proper functioning of the Guard Gates. Boott will continue these practices under the new FERC license.

The combination of past and present land use activities in and around the Project area have contributed and will likely continue to contribute to the accumulation of waterborne trash within the Project's canal system that occur in the study area today (e.g., industrialization, commercial development, residential areas in close proximity to canals, etc.). However, the complexity and diversity of historical and current land use activities in the study area create a problem for tracing and identifying the sources of waterborne trash and its movement and distribution within the study area. Waterborne trash consisted of common materials such as foam board pieces, plastic cups, foam plates, foam bait containers, shoes, plastic bottles, and organic debris. It is well known that many types of land uses contribute to the accumulations of waterborne trash including stormwater drainage systems, upstream sources, inappropriately discarded trash, natural events (woody debris), densely populated areas, etc. Roads, construction, recreation, residential developments, and commercial and industrial developments all can contribute to the problem. Ongoing Project operation and maintenance has very little potential to cause and/or significantly contribute to the waterborne trash accumulation areas observed during the study.

Existing Project facilities are an integral part of the river's ecologic and aesthetic character. The Licensee is not proposing to modify Project operations. Current Project operations do not involve activities that directly affect aesthetics. Continued operation of the Project will help maintain the aesthetic quality of the Merrimack River by providing a continuous flow in the Project's bypassed reach and downstream areas. No impacts on aesthetic resources are expected as a result of continued Project operations.

E.7.7.2.2 Socioeconomic Resources

As previously described in this application, the Project is located within the historic infrastructure of the LNHP. Tourists are drawn to the city of Lowell to witness the historic site of the Industrial Revolution of the United States. Boott is not proposing to modify Project operations. As such, the continued operation of the Project as proposed by the Licensee is not expected to have any adverse effects on socioeconomic resources.

E.7.7.3 Proposed Environmental Measures

Boott proposes to continue operations of the Project with certain PM&E as outlined above in Section E.6.2.

E.7.7.4 Unavoidable Adverse Impacts

The continued operation of the Project as proposed by the Licensee is not expected to have any unavoidable adverse effects on aesthetic or socioeconomic resources.

E.7.8 Cultural Resources

The subsections below describe cultural resources in the vicinity of the Project and consider the effects of continued operation of the Project as proposed by the Licensee on these resources.

In considering a new license for the Project, the Commission has the lead responsibility for compliance with applicable Federal laws, regulations, and policies pertaining to historic properties, including the National Historic Preservation Act of 1966, as amended (NHPA)[31]. Section 106 of the NHPA (Section 106)[32] requires Federal agencies to consider the effects of their undertakings on historic properties and to afford the Advisory Council on Historic Preservation (ACHP) a reasonable opportunity to comment.

The term "historic property" is defined in the implementing[33] regulations as any precontact or historic period district, site, building, structure, or individual object included in or eligible for inclusion in the National Register of Historic Places (NRHP), including any artifacts, records, and remains that are related to and located within historic properties, and properties of traditional religious and cultural significance that meet the NRHP criteria. The criteria for evaluating properties for inclusion in the National Register (36 C.F.R. Part 60) has been established by the Secretary of the Interior. In accordance with the criteria, properties are eligible if they are significant in American history, architecture, archaeology, engineering, or culture. The quality of significance is present in historic properties that possess integrity of location, design, setting, materials, workmanship, feeling, association, and:

1. That are associated with events that have made a significant contribution to the broad patterns of our history;
2. That are associated with the lives of persons significant in our past;
3. That embody the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant or distinguishable entity whose components may lack individual distinction; and/or
4. That have yielded or may be likely to yield information important in prehistory or history.

The regulations implementing Section 106 are intended to accommodate historic preservation concerns with the needs of federal undertakings through a process of consultation among agency officials, Federally recognized Native American tribes, SHPO, Tribal Historic Preservation Officers (THPO), and other parties, including the public, as appropriate. By letter dated April 26, 2017, the Commission initiated consultation under Section 106 with Federally recognized Native American tribes,

[31] 54 U.S.C. §300101 et seq.

[32] 54 U.S.C. §306108

[33] 36 C.F.R. Part 800 – The Protection of Historic Properties

including the Mashpee Wampanoag Tribe, Narragansett Indian Tribe, Stockbridge Munsee Tribe of Mohican Indians, and Wampanoag Tribe of Gay Head (Aquinnah).

The Commission designated Boott as its non-federal representative for purposes of conducting informal consultation pursuant to Section 106 via the June 15, 2018 NOI to file a License Application for a New License and Commencing Pre-filing Process.

E.7.8.1 Affected Environment

E.7.8.1.1 Area of Potential Effects

The area of potential effects (APE) for any undertaking is defined in 36 C.F.R. §800.16(d) as the geographic area or areas within which an undertaking may directly or indirectly cause alterations in the character or use of historic properties, if any such properties exist. The APE is influenced by the scale and nature of an undertaking. Although the Project's potential effects are limited by the nature of this undertaking (the relicensing and continued operation and maintenance of existing hydroelectric facilities), the Project has the potential to affect historic properties directly or indirectly (should any such properties exist). As described in the PAD, Project-related effects on historic properties may potentially result from (1) the Project's operations, (2) potential enhancement measures at the Project, and (3) routine maintenance activities. Potential enhancement measures at the Project (e.g., development of new recreation access areas) could result in ground disturbance which has the potential to disturb intact archaeological deposits, should any be present. Routine maintenance activities at the Project could result in ground disturbance and could also affect the integrity of historic buildings and structures.

Consistent with the scope of potential effects on historic properties, Boott proposed to define the APE for relicensing the Project as the following:

> *The APE for the Lowell Hydroelectric Project is the lands within the defined FERC Project boundary.*

Since the Project boundary encompass all lands that are necessary for the Project's purposes, the definition of the APE is consistent with the 36 C.F.R. §800.16(d) and the manner in which the Commission has defined the APE for similar hydroelectric projects. The existing Project boundary is presented in Figure E.1-1.

As stated elsewhere in this application for license, Boott proposes to remove the four mill power stations and associated canal infrastructure from the new FERC license and associated Project boundary.

E.7.8.1.2 Cultural Context

Precontact Period

For several thousand years, the Pawtucket Falls was a thriving center of Native American economic and cultural activity. The annual run of anadromous fish drew Pennacook Native Americans from a wide area of northern New England, and two subtribes, the Pawtuckets and Wamesits, established villages on the flats near the bend of the Merrimack below the falls. Salmon, sturgeon, shad, and alewives were harvested with nets, spears, and barbed arrows. The fish provided not only a large portion of the Native Americans' yearly protein intake, but also served as fertilizer for the nearby agricultural fields. The site retains its Native American name today, for "Pawtucket" means rapids or falls in the Algonquin dialect of its early settlers (Boott Mills 1980).

There are three pre-Contact archaeological sites recorded in the area of Lowell Park, however, many more exist along the Merrimack River both upstream and downstream of the Project. Many Archaic Period village sites, camp sites, and fishing grounds are documented in the vicinity of the Project (MADCR 2014). Boott distributed PAD questionnaires to the MHC and the NHDHR; however, no responses were received.

According to the MHC's survey map of prehistoric sites in Lowell, a major Native American archeological site is on the flood plain beyond the bluff. Much of this area, site of Native American campgrounds and cultural activities associated with fishing, has been disturbed by a series of construction projects for roads and buildings. The likely locations of artifactual remains lie northeast of the path followed by the intake channel (Boott Mills 1980).

E.7.8.1.3 Historical Context

This section provides an historical context of the Project Area from early Anglo-European settlement through the Industrial Revolution.

Anglo-European settlers gradually acquired Native American homelands, and private ownership divided the once common land into scattered farms. Proprietors of riverbank properties even acquired legal title to the fishing rights on sections of the rapids. Although remnants of former Native American bands made annual trips to fish at the Pawtucket Falls as late as the 1840s, they were considered a quaint curiosity in the growing industrial community (Boott Mills 1980).

Background of Industrial Lowell

A number of circumstances are responsible for Lowell becoming America's first industrial city, particularly, the existence of the great waterpower potential at the Pawtucket Falls. Although a transportation canal around the rapids at Lowell was completed in 1796, the manufacturing potential of the site was not fully appreciated until 1821. The Boston Associates chose the site of the Pawtucket Falls for their new textile manufacturing community (Boott Mills 1980). The Boston investors acquired control of Proprietors of the Locks and Canals on Merrimack River, the company that had built the Pawtucket navigation canal and that, due to the success of the competing Middlesex Canal (direct route to Boston), was not doing well financially. The Boston investors and other industrialists formed a series of textile corporations in Lowell. The old canal company was set up to build canals, sell mill sites, manufacture machinery, and lease waterpower to the textile manufacturers (Boott Mills 1980). The Pawtucket Canal became the feeder for a complex system of power canals beginning in 1822. By 1826, two canals branched from the Pawtucket and four additional canals were already envisioned. Ten years later, the expanded system was complete. Water drove the machinery of mills located on two distinct levels, with the tailraces of mills on the upper level emptying into canals leading to lower level mills. By 1846, when a second major expansion of the canal system began, ten textile mill complexes and a machine shop received their power from Proprietors of the Locks and Canals on Merrimack River (Boott Mills 1980).

General History of the Northern Canal Area

Since 1826, engineers had been able to increase the flow into the Lowell Canal system by constructing dams at Pawtucket Falls. The first was a crude wooden structure; but by 1830, a masonry dam seated on heavy wooden cribbing was helping to maintain a "pond" behind the falls. Three years later, workmen added two more courses of granite headers and raised wooden flashboards. This raised the level of the upper river and diminished its current for over 18 miles upstream. However, the dam did not meet the water needs of the growing industrial city for long as the demand for waterpower continued to increase yearly as the textile corporations expanded their manufacturing operations. Power was continually scarce in the dry summer months; and by the 1840s, shortages were common throughout the year. One problem was the severe friction losses in the canals created by greater flow rates. When mills needed more water, the current had to increase to supply this demand. Increased current produced friction, which actually dropped the level of water in the canals and reduced the head, or potential to generate power. Thus, the mills could only get a greater flow of water by giving up some of the head that they also needed. In times of freshets, river water entering the tailraces of mills impeded their wheels. Such backwater conditions placed excessive demands on the canal system (Boott Mills 1980).

James B. Francis, the British-born chief engineer of Proprietors, proposed the construction of a second feeder canal. This huge waterway would bring additional water into the system and allow a reduction of current in most of the canals. To make such a plan effective, however, two conditions had to be met. First, Locks and Canals would have to prohibit the use of water for manufacturing at night, so that the river's flow could be ponded until the morning. Second, the power company would have to control the outlets of the major lakes that fed the Merrimack River. Using the lakes as reservoirs, Lowell would then have a source of extra water in dry seasons (Boott Mills 1980).

With booming economic conditions in American textile manufacturing in the 1840s, the Essex Company of Lawrence and the Locks and Canals acquired control of over 100 square miles of lake surface in New Hampshire. James. B. Francis selected a new route for a second feeder canal. The route ran parallel to the river for over 2,000 feet, then turned inland to join the Western Canal. The route required Francis to build a "Great River Wall" to hold his canal above the Merrimack rapids and also required him to (1) rebuild a large part of the Pawtucket Dam, (2) construct sophisticated gate controls, and (3) modify the existing canal system to integrate it with the new canal (Boott Mills 1980).

The construction of the Northern Canal, under the supervision of James B. Francis in 1846-1847, was one of the most impressive achievements in the history of American engineering. The vast undertaking was the culmination of efforts to harness the flow of the Merrimack River at Pawtucket Falls to drive the textile machinery of the Boston investors. When completed, the project set new standards in civil and hydraulic engineering and introduced the famous "Francis" turbine to the world (Boott Mills 1980). The Northern Canal brought water into the system with a higher head than had been previously possible, and it reversed the current in the Western Canal from the junction to the Swamp Locks Basin. Water from the Northern Canal supplied the demands of the Tremont, Suffolk, and Lawrence Mills. Once Francis had completed the Moody Street Feeder in 1848, the Northern Canal also fed the Merrimack Canal through three brick vaulted tunnels. A smaller underground passage, known as the Boott Penstock, transferred some of this flow from the Merrimack Canal to the end of the Eastern Canal, where an adequate water level had always been hard to maintain (Boott Mills 1980). After testing the results of his physical improvements to the system, Francis arranged for redistribution of power and an increase in the number of "mill powers" leased to each company. Because of the limitations of the old Pawtucket Canal as the sole feeder, only 91 mill powers had been leased up to that time. The Northern Canal enabled the chief engineer to lease 139 mill powers, a gain of more than 50 percent. These were "permanent mill powers" to be supplied in all seasons; for most of the year, the corporations could also purchase "surplus" mill powers at an inexpensive rate. The mill complexes were assured of almost 12,000 gross horsepower, even in summer (Boott Mills 1980).

Francis, acting as "The Chief of Police of Water," tried to prevent waste in the system and developed techniques to monitor the water use by individual corporations. When the flow in the river was low, he even closed the gates of the Northern Canal during the noon break. His 1846 tests of Uriah Boyden's outward-flow turbines in the Appleton Mills led to the development of the first "Francis" turbine, which was used to raise and lower the headgates within the Pawtucket Gatehouse. The original Francis turbine and drive belts remain in the Pawtucket Gatehouse, but are no longer used. This work convinced Francis that the corporations should switch from breastwheels to more efficient hydraulic turbines. In this way, they could produce more net horsepower from each "mill power" delivered to their sites. Also, turbines, which ran well underwater, could generate during the "backwater" conditions that ruined the efficiency of breastwheels. The widespread conversion to turbines in Lowell took place during and immediately following the construction of the Northern Canal. Francis' Northern Canal and its associated structures remain one of the most important historic engineering resources in the Northeast (Boott Mills 1980).

Historic Resources

In 1976 the Locks and Canals Historic District was listed on the National Register of Historic Places. The Locks and Canals Historic District includes the City of Lowell's canal system, surviving millyards, and other industrial-related resources. In 1977, the Locks and Canals Historic District was designated a National Historic Landmark (NHL), the nation's highest level of historic significance and recognition. In 1978, Congress passed the Lowell Act, which recognized the historical value of this industrial area and established the Lowell Park and Lowell Historic Preservation District, stating:

> *"…certain sites and structures in Lowell, Massachusetts, historically and culturally the most significant planned industrial city in the United States, symbolize in physical form the Industrial Revolution…"*

The Lowell Historic Preservation District surrounds Lowell Park as a buffer zone and enables federal assistance in the preservation and revitalization of the City of Lowell, while Lowell Park consists of the areas indeed for intensive visitor use in the interpretation of the City of Lowell and its canal system. The intention of the establishment of the Lowell Park and Lowell Historic Preservation District is to preserve and interpret the nationally significant historical and cultural sites, structures, and districts in Lowell, Massachusetts.

A Cultural Resources Inventory of the Lowell National Historical Park and Preservation District was prepared for the NPS in 1980. This inventory was completed in response to the 1978 legislation establishing the Lowell National Historical Park and the Lowell Historic Preservation District. This legislation was two-fold in that it created a park as well as a historic preservation district. The legislation outlined broad policies and goals of the federal commitment and required careful planning. To address this need for planning, the cultural resources inventory was conducted to assess the resources and aid in future planning. The defining features of the Locks and Canals Historic District and Lowell National Historic District are discussed in further detail below.

Locks and Canals Historic District

The Locks and Canals Historic District was listed on the National Register in 1976 and became a National Historic Landmark in 1977. The Locks and Canals Historic District encompasses all the canals in Lowell (built between 1793 and 1848), their associated locks, and the mills that were powered by the canals. This district contains features of the Lowell Project. There are approximately five miles of canals, and the associated mill yards increase the acreage of the district to approximately 100 acres. The canals are contiguous and meander throughout the city. The mill buildings and yards are all associated directly with a canal, and three boarding houses, not contiguous to the canals but built by mill owners for their workers, are also included in the district. The main components of the Locks and Canals Historic District are:

- Lock House
- Francis Gate and House
- Sluice Gate House
- Northern Canal Gatehouse
- Locks and Canals Blacksmith Shop
- Gate Keeper's Cottage
- Northern Canal
- Northern Canal Walk and Great River Wall
- Suffolk Millyard
- Tremont Gatehouse
- Tremont Yard
- Lawrence Yard
- Moody Street Feeder
- Moody Street Feeder Gatehouse
- Boott Mills
- Massachusetts Mills
- Boot Mills Boarding House
- Massachusetts Mills Boarding House

- Lower Locks, Pawtucket Canal
- Bigelow Yard
- Hamilton Yard
- Eastern canal
- Lower Pawtucket Canal
- Appleton Mills
- Hamilton Canal
- Swamp Locks
- Merrimack Canal
- Lowell Machine Shop
- Proprietors of Locks and Canals Yard
- Western Canal
- Upper Pawtucket Canal
- Pawtucket Dam
- Suffolk Manufacturing Company Boarding Houses

The Locks and Canals Historic District is significant for its contributions to the development of Lowell as the first great industrial city in the United States.

Lowell National Historical Park

The LNHP and Preservation District was listed on the National Register in 1978. The LNHP Preservation District includes within its boundaries an approximate 5-mile power canal system, a portion of the central business district, and three major mill complexes. The area within the park boundaries totals 134 acres, but with only NPS ownership of a handful of buildings with other property privately owned. The Lowell Historic Preservation District includes the mills or mill sites of most of the rest major textile corporations, the remainder of the historic central business district, and areas along the Concord River where smaller factories flourished outside the main waterpower system. There are 895 properties within Lowell Park and the Lowell Historic Preservation District and are classified as follows:

- 307 residential buildings
    - 147 single family
    - 62 duplexes
    - 99 multiple family
- 210 commercial buildings
- 130 buildings within textile mill complexes
- 27 other industrial structures
- 16 schools
- 9 churches
- 24 government buildings
- 92 vacant lots
- 33 components of the canal system
- 11 bridges
- 37 miscellaneous structures (theaters, parking garages, playgrounds, etc.)

In terms of the condition, the properties (excluding the canals) are classified according to 1979 data as follows: 56 in excellent condition, 412 in good condition, 244 need minor repair, 70 need major repair, and 8 are derelict. In terms of period, the structures range in period from pre-1820 to post-1950 with the greatest number of structures dated in the 1890s and from 1900-1925.

Lowell Park and the LHPD's most important historical resources are the canal system, the remaining major mill complexes, and the central business district's nineteenth century commercial buildings. The District also includes elements of other historic industrial enterprises, particularly along the Concord River. Residential properties within the District represent most of the range of styles, forms, and periods of Lowell's architectural history, but these houses generally fall short of Lowell's historic houses outside the Lowell Historic Preservation District's in quantity, quality, and concentration.

Lowell Canal System

The Lowell Canal System has also been recognized for its significance within the field of engineering. The American Society of Civil Engineers designated the "Lowell Waterpower System" as a Historic Civil Engineering Landmark in 1984, and the American Society of Mechanical Engineers designated the "Lowell Power Canal System and Pawtucket Gatehouse" as a Historic Mechanical Engineering Landmark in 1985 (MADCR 2014).

E.7.8.1.4 Cultural and Historical Resource Studies

Pursuant to the approved RSP and SPD, Boott filed with the Commission the following studies relating to historical and cultural resources:

- Water Level and Flow Effects on Historic Resources Study (HDR 2021b),
- Historically Significant Waterpower Equipment Study (Gray & Pape 2021), and
- Resources, Ownership, Boundaries and Land Rights Study (HDR 2021c).

Significant prior research and studies have been conducted to document historic buildings and structures within the City of Lowell, including Project facilities. In 1976, the Historic American Engineering Record (HAER) documented the history of the canal system in Lowell. The HAER study included detailed narratives, photographs, drawings, and maps of the historic canal system. The Lowell National Historical Park and Historic Preservation District Cultural Resources Inventory (Shepley, 1981) provides a comprehensive and detailed inventory of historic buildings and structures within the park unit and surrounding preservation area. Later studies, including the 1984 HAER documentation of the Boott Cotton Mills Complex, documented specific resources within the park unit. While these studies have documented historically significant buildings, structures, and some of the hydroelectric equipment associated with the Project, no systematic survey of historically significant waterpower equipment associated with the Project has been conducted until now.

Ownership, boundaries, and land/access rights within the FERC Project Boundary in downtown Lowell are complex. The licensee owns some, but by no means all, of the existing Project works. The Project is situated within several different and overlapping parks, and preservation/conservation districts. The canal system, the downtown mill sites, and many of the Project's civil works, are contributing resources to Lowell Locks and Canals NHL District. The canal system and many Project facilities are also located within the LNHP and larger Lowell Historic Preservation District. The park is by design a partnership park in which federal, state, and local governments as well as the private sector and local community carry out the legislative intent of the park unit. The Project's Hamilton, Assets, Bridge Street, and John Street power stations and turbines are housed in large old mill buildings within the Lowell National Historical Park and Lowell Historic Preservation District. As stated elsewhere in this application for license, Boott proposes to remove the four mill power stations and associated canal infrastructure from the new FERC license. Boott will continue to manage the canal structures, water levels and flows using best practices and consistent with current agreements with the NPS and other stakeholders.

Water Level and Flow Effects on Historic Resources Study

In accordance with the Commission's SPD, Boott conducted a Water Level and Flow Effects on Historic Resources Study. The objective of this study was to analyze the potential effects of water level fluctuations from Project operations in the headpond, Northern Canal, and the Upper Pawtucket Canal (extending upstream from the Guard Lock Gate Complex to the mainstem of the Merrimack River) on historic structures with a focus on the Pawtucket Gatehouse, the Northern Canal Waste Gatehouse, the Guard Lock and Gatehouse Complex, and the Great Wall. Methods and results are described in detail in Boott's study report (HDR 2021b) which was filed with the Commission on March 5, 2021.

The results indicated the magnitude of fluctuation in the Project's headpond and the Pawtucket Canal has been significantly reduced by the implementation of the pneumatic crest gates, as shown by post crest gates operations presented in Figure E. 7-39 and pre crest gate operations shown in Figure E. 7-40 below. Water levels in the Pawtucket Canal upstream of the Guard Locks complex are essentially the same as the Project impoundment and remained below the normal headpond level of 92.2 ft NGVD29 throughout the 2020 study period except for one occasion. The elevation of the Guard Locks complex walkway (92.45 ft), the clapboard siding (92.45 ft), and the bottom of the mid-level windows (94.08 ft) are all above the normal water level of the Upper Pawtucket Canal. Only river flows in excess of 35,000 cfs could cause the Upper Pawtucket Canal to inundate the wooden structural elements of the Guard Locks complex; however, these conditions are outside of the ability of the Project to control the impoundment water level and therefore not attributable to Project operations.

The operation of the Northern Canal has caused periodic inundation of the sill at the Northern Canal Waste Gatehouse (Figure E.7-41). This inundation may be one factor in the continued deterioration of the gatehouse's southern sill. Spray from the canal spillway may also be contributing to deterioration along the eastern end of the northern sill.

Figure E.7-39. Project Headpond Water Surface Elevation During 2020 Monitoring Period

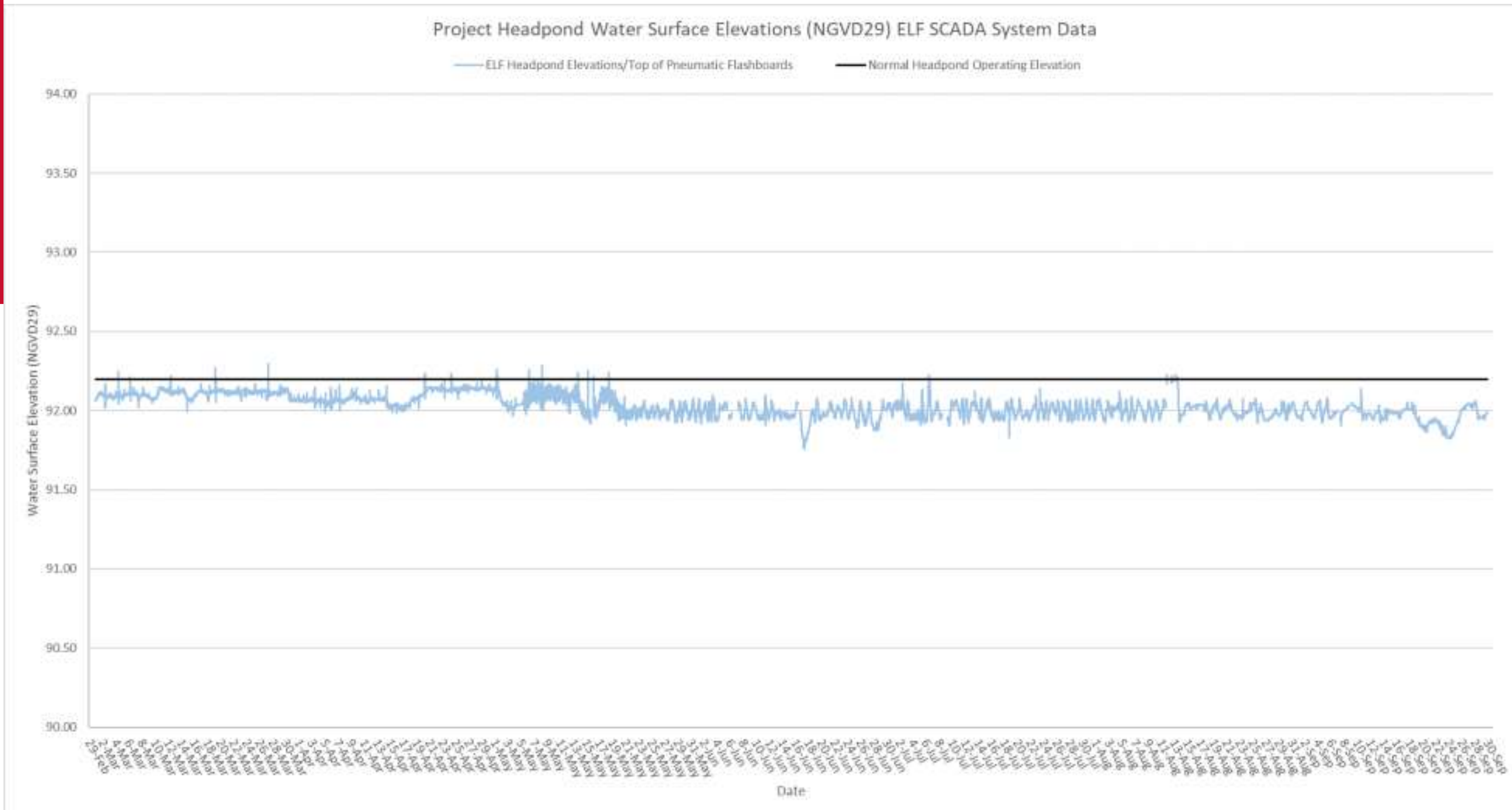


Figure E.7-40. Merrimack River – Pawtucket Dam Headpond Elevations for Period of Record (1995-2010)

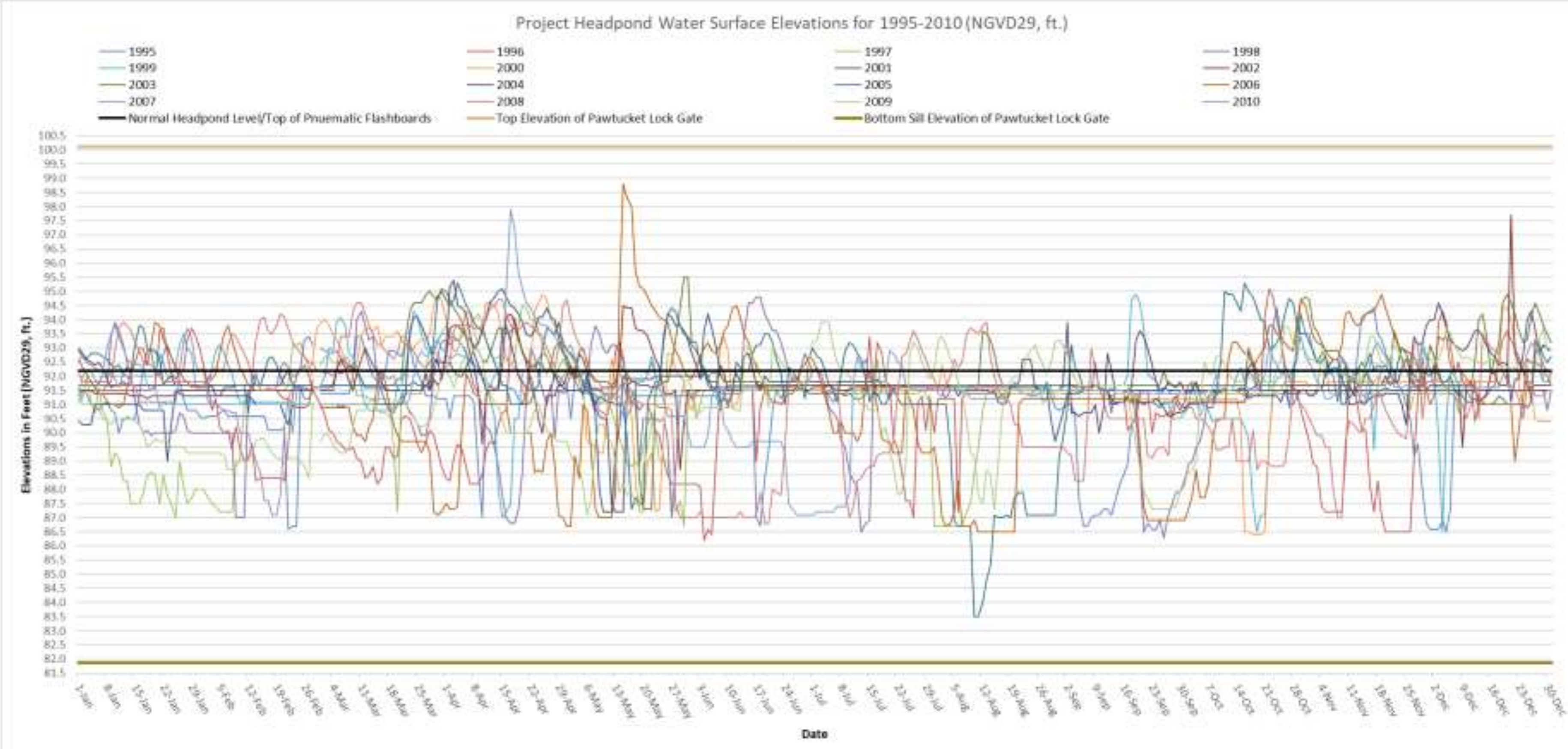
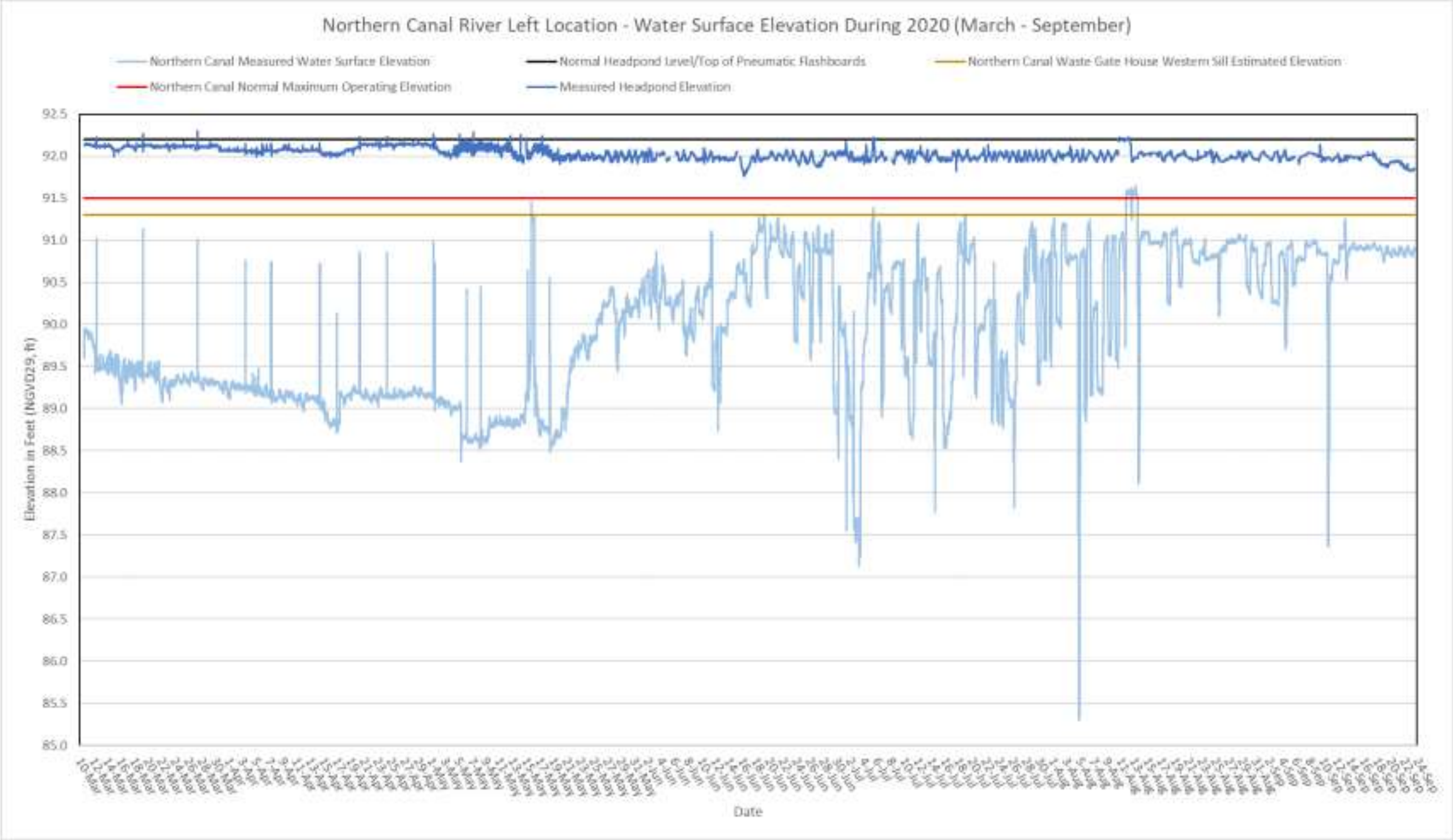


Figure E.7-41. Northern Canal River Right Location - Water Surface Elevation During 2020 Monitoring Period



The results of the study indicate the wooden structural elements of the historic resources located along the Upper Pawtucket and Northern Canals appear most susceptible to damage from submergence, periodic inundation, and waterborne trash. While the magnitude of fluctuation in the Project's headpond and the Pawtucket Canal has been significantly reduced by the implementation of the pneumatic crest gates, the Merrimack River is subject to routine seasonal high flow events. High flow events can also mobilize waterborne trash and debris that have the potential to damage wooden structural elements; however, neither high flow events nor the presence of waterborne trash and debris in the Merrimack River are attributable to Project operations.

While normal Project operations do not appear to be adversely affecting the Pawtucket Gatehouse Lock Structure beyond normal wear, at least one incident appears to have contributed to recorded damage to the upstream miter gate (Figure E.7-42). The canal surge event that occurred in 2018 was caused by the malfunction of a water level transducer. The effect of the resulting surge was exacerbated by the practice of chaining the gates closed. This anomalous incident does not represent normal Project operations, and Boott is repairing the damage to the gate.

Figure E.7-42. Damage to the Northern Canal Lock Timber Gate

Historically Significant Waterpower Equipment Study

In accordance with the Commission's SPD, Boott conducted a Historically Significant Waterpower Equipment Study to identify historically significant waterpower equipment for potential future interpretation, exhibition, or as scrap equipment to maintain and operate other historic machinery. Methods and results are described in detail in Boott's study report (Gray and Pape 2021) which was filed with the Commission on February 25, 2021.

The results indicated that it is the totality of the system of waterpower and water-control machinery at Lowell that is historically significant. Removal and replacement of individual pieces of equipment was nearly continual, from the day the system first became operational. Removal or alteration of existing equipment would constitute an adverse effect upon the qualities that make the existing system historically significant if they prevented or precluded the system from operating. Several pieces of equipment appear to be historically significant, distinct from their role as a part of the larger system. These pieces of equipment include the surviving 1870 hydraulic gate hoist system at the Pawtucket Canal Guard Locks, and the Francis turbine powered belt-and-line shafting gate operating system at the Pawtucket Gatehouse. The extant gate operating system at the Moody Street Feeder Gatehouse is likely also historically significant.

Resources, Ownership, Boundaries, and Land Rights Study

Pursuant to the approved study plan, Boott conducted a Resources, Ownership, Boundaries, and Land Rights Study to determine current ownership of resources within the canal system and existing Project Boundary, and document maintenance responsibilities, access rights, and FERC jurisdiction. The methods and results of the Resources, Ownership, Boundaries, and Land Rights Study filed with the Commission on February 25, 2021.

Ownership, easement rights, and use of the canal system in Lowell are complex, with intersecting roles between public agencies and private entities at the local, State, and Federal level. Boott conducted desktop research and a literature review to compile and review available ownership and rights documentation to obtain a better understanding of the rights and responsibilities related to resources within the Project Boundary. As appropriate and relevant, public guidance and conceptual planning and/or management documentation was reviewed by Boott including the 1977 Report of the LHCDC, the 1980 Details of the Preservation Plan, the 1981 FGMP, and the 1990 Preservation Plan Amendment. Additionally, Boott reviewed and analyzed the three legal documents that establish most of the ownership, responsibilities, and land rights to the Lowell canal system. The 1984 Deed, Bill of Sale and Grant of Easements, also known as the "Great Deed" details the sale of portions of the Project from the Proprietors of the Locks and Canals on the Merrimack River (Proprietors) to Boott, as well as associated access and repair easements. The 1986 Order of Taking details the take of properties, rights, and responsibilities from Boott and Proprietors to the Commonwealth, operating through MADCR. The 1995 Grant of Easement describes the easement rights provided to the NPS from MADCR for specific properties and parcels around the canal system.

The conceptual framework for the rights and responsibilities for management of the Lowell canal system remain consistent within the 1977 Report of the LHCDC, the 1980

Details of the Preservation Plan, the 1981 FGMP, and the 1990 Preservation Plan Amendment. MADCR and NPS are presented as the main parties responsible for developing, renovating, and maintaining the major elements of the canal system. In the 1977 Report of the LHCDC, agency responsibilities were characterized and are shown below in Table E.7-32.

Table E.7-32. Agency Responsibilities Identified in 1977 Report of the LHCDC

Agency	Responsibilities
NPS	interpretation, park wide downtown "cross-section" of 19th Century Lowell (including preservation, building and open space improvements, transportation, and visitor services)
MADCR	canals, riverbanks, and related recreational areas gatehouses, locks and dams barge system

Ownership of the Lowell canal system is largely determined by the 1984 Great Deed and 1986 Order of Taking. Components of the canal system are owned by Proprietors, Boott, and MADCR. Proprietors owns most of the Pawtucket Canal and Lower Pawtucket Canal, as well as all or portions of associated structures in those canals (e.g. Swamp Locks Dam, Lower Locks Dam, and the Guard Locks and Francis Gate). Boott is not known to own any structures of or within the Pawtucket or Lower Pawtucket Canal.

Boott owns the Northern Canal, Western Canal, Merrimack Canal, Eastern Canal, and Hamilton Canal. Boott owns specific dams, lock structures, and hydroelectric equipment within the canals they own. The specific structures fully owned by Boott within these canals include Hall Street Dam, Lawrence Dam, Boott Dam, Rolling Dam, Merrimack Dam, Merrimack Gates, YMCA Gates, and the Moody Street Feeder. Boott owns hydroelectric equipment located inside most gatehouses, such as the Boott Dam Gatehouse and Tremont Gatehouse, but Boott does not own the gatehouse buildings.

MADCR owns most of the gatehouses throughout the canal system (e.g. Pawtucket Gatehouse, Lower Locks Gatehouse, and Swamp Locks Gatehouse, Rolling Dam Gatehouse, Hamilton Gatehouse, and Massachusetts Wasteway Gatehouse) and this is largely determined based on elevation.

Easement rights to structures of the Lowell canal system are held by Proprietors, Boott, MADCR, and NPS. In the 1984 Great Deed, Boott obtained easement rights, in common with Proprietors, to the Pawtucket Canal and structures of the Pawtucket Canal. These easement rights allow Boott to access, operate, maintain, repair, and replace the Pawtucket Canal and structures of the Pawtucket Canal. In the 1986 Order of Taking, MADCR obtained a permanent and exclusive easement to structures of the canal system, including canal walls, beds, and bottoms, for purposes including conservation, preservation, maintenance, and other uses consistent with the use of the system as a park. NPS obtained similar easement rights through the 1995 Grant of Easement from MADCR, including the right to maintain, repair, conduct grounds maintenance, and operate boat tours.

An exclusive easement allows the easement holder to control and implement specific purposes as if they are the owner. MADCR has a permanent and exclusive easement over most of the canal system for the following purposes, which include the following enhancements and upgrades:

a) Support of all fixtures or structures of the Commonwealth now or hereafter attached;
b) Preservation and conservation;
c) Supplemental maintenance in addition to that performed by the Condemnees (the prior or current owner) and their successors and assigns;
d) Landscaping and erection of exhibits and structures;
e) Placement of barriers and fences;
f) Placement and attachment of docks, wharves, walls, and boat ramps of a temporary or permanent nature;
g) Placement of lighting and other utilities;
h) Operation and maintenance of boat locking chambers, if any, for any and all purposes; and
i) Any and all other uses consistent with the operation of the canal system as a park.

Given that MADCR's exclusive easement is throughout most of the canal system, it overlaps significantly with Boott and Proprietors' owned property. It is understood that Boott, Proprietors, and MADCR have a duty and right to maintain properties under their ownership to achieve a standard of reasonable care. Owners do not have an obligation or duty to upgrade or enhance their property. However, MADCR's exclusive easement throughout most of the Lowell canal system gives them the right to implement any of the purposes noted above, which include enhancements and upgrades, as if they were the owner.

The Resources, Ownership, Boundaries, and Land Rights Study also determined different resource rights. The results indicated that recreational resource rights are exclusively owned by MADCR. In early conceptual planning documents, MADCR was presented as the party that would own, implement, and manage any recreational resources. MADCR obtained such rights in the 1986 Order of Taking, including the exclusive right to use water for recreational, educational, or navigational purposes, and permanent and exclusive rights to build wharves, docks, and boat ramps. The two other identified resources are air resource rights, and water and flowage rights. Air resource rights have been owned by MADCR since issuance of the 1986 Order of Taking. Water and flowage rights are owned by Boott and Proprietors, as established in the 1984 Great Deed.

E.7.8.2 Environmental Analysis

The NHPA establishes the statutory responsibility of federal agencies to consider historic properties under their jurisdiction. Section 106 requires federal agencies to consider the effects of their undertakings on historic properties listed in or eligible for inclusion in the NRHP. The Commission's issuance of a new license for the Project is defined as an undertaking under the NHPA and is, therefore, subject to the provisions of Section 106 and its implementing regulations at 36 C.F.R. Part 800.

FERC's SD2 identified effects of continued Project operations on cultural and historical resources as potential resource issues. Specifically, SD2 identified the following potential resource issues related to cultural and historical resources to be analyzed for site-specific effects:

- Effects of continued project operation and maintenance on historic resources, archeological resources, and traditional cultural properties that are included or may be eligible for inclusion in the National Register of Historic Places.
- Effects of continued project operation and maintenance on properties of traditional religious and cultural importance to an Indian tribe.

During the previous relicensing, Boott consulted extensively with the Massachusetts SHPO and NPS to avoid destroying historic Waste Gates on the Northern Canal and to fund repairs to the Northern Canal Gates to restore them to their original condition. The proposed powerhouse was relocated, and fish passage facilities were modified to avoid any impacts to the Northern Canal Gatehouse. In addition, the Owner constructed a new set of locks in the Northern Canal to provide boat passage, to avoid any loss of historic use of the canal system. Furthermore, additional mitigative measures were undertaken by the Licensee to minimize impacts of new structures introduced into the historic district (Cleantech Analytics 2017).

Current Project operations may be a contributing factor to the continued deterioration of the Northern Canal Waste Gatehouse's southern and northern sills. The Northern Canal periodically inundates the southern sill, and spray from the Northern Canal spillway may be contributing to the deterioration of the northern sill. Repeated inundation and drying of timber sills has the potential adversely affect the integrity of the Northern Canal Waste Gatehouse; however, other factors unrelated to Project operations have also likely contributed to the ongoing deterioration of the sills, including the age of the wooden timbers, general maintenance, weathering, and atmospheric conditions.

Boott has not identified any other historic properties that are being adversely affected by the ongoing operation and maintenance of the Project. As noted above, Boott determined at least one incident that appears to have contributed to recorded damage to the upstream miter gate at the Pawtucket Gatehouse. This anomalous incident does not represent normal Project operations, and Boott is repairing the damage to the gate.

Boott is not currently proposing modifications to the Project's operations or any land-clearing or land-disturbing development activities within the APE that would result in an impact to any archaeological sites, historic architectural resources, or areas that have been identified as having moderate to high potential for containing archaeological sites.

In addition, only one out of the nine tribes, the Mashpee Wampanoag Tribe, responded to FERC's initial tribal consultation letter dated April 26, 2017 and did not identify any concerns related to the Project pertaining to cultural resources.

While Boott is not proposing modifications to the Project's operations that have the potential to adversely affect historic properties, Boott is proposing to remove the four mill power stations and associated canal infrastructure from the Project boundary and the new FERC license. Pursuant to 36 C.F.R § 800.5(a)(2)(vii), the removal of the downtown canal system from FERC's federal jurisdiction could result in an adverse effect if removal is done "without adequate and legally enforceable restrictions or conditions to ensure long-term preservation of the property's historic significance." As noted above, the downtown canals are located within the Lowell National Historical Park, the Locks and Canals Historic District (a National Historic Landmark) and the Lowell National Historical Park and Preservation District, which are listed in the National Register of Historic Places. Accordingly, Boott expects that potential effects will be limited as the downtown canal system and associated structures will still remain under the federal and state oversight provided by the NPS and MADCR.

As reported in the Resources, Ownership, Boundaries, and Land Rights Study Report (HDR 2021c), Boott owns all the canals except the Pawtucket Canal and Lower Pawtucket Canal, but MADCR and NPS have various easement rights to the downtown canal system for purposes of preservation, conservation, and other uses consistent with that of a park. MADCR has a permanent and exclusive easement to the entire canal system for all uses consistent with the operation of the canal system as a park, which gives MADCR the right to implement preservation and conservation measures as if they were the owner of the structures. Boott does not own most of the historic gatehouses, dams, and locks that will be removed from the Project boundary with the canals; these are mostly owned by MADCR and Proprietors. Boott does have certain easement rights to these structures they do not own, but those easement rights are mostly limited to hydropower maintenance and operation. While the removal of the downtown canal system may result in an adverse effect, the system will remain protected by federal and state oversight, and Boott will still be obligated to and limited by its legal agreements with MADCR and NPS. Further, and as discussed below, Boott is proposing to develop a decommissioning plan to address, *inter alia*, the final disposition of the canal system, turbine-generator units, water conveyance structures, and mechanical and electrical components.

E.7.8.3 Proposed Environmental Measures

- Boott proposes to continue operations of the Project with certain PM&E measures required by the existing license. This includes continued adherence to Article 33, which requires that prior to the commencement of any construction activities inside the Project boundary, Boott will cooperate with the Massachusetts SHPO and the NPS to carry out a mitigation program for avoiding or minimizing adverse effects on the Locks and Canals Historic District and the Lowell National Historical Park.
- Boott understands that removal of the fifteen turbine-generator units and canal system from its license will require a decommissioning plan to define the final

disposition of the canal system, turbine-generator units, water conveyance structures, and mechanical and electrical components. A decommissioning plan is also necessary to protect the public from any safety, dam safety, or environmental concerns. Boott will develop a decommissioning plan for each of the four downtown power stations and the canal system. In developing the decommissioning plan, Boott will consult with the NPS, MADCR, City of Lowell, and the MHC. Boott will file a decommissioning plan for the Commission's approval within 18 months of issuance of a new license.

Within one year of license issuance, Boott will develop an HPMP for the Project that will describe appropriate management measures to avoid, minimize, or mitigate adverse effects on historic and archaeological resources over the term of the new license issued for the Project. The measures provided in the HPMP will direct the Licensee's management of NRHP-listed or eligible historic properties within the Project's APE, which is preliminary defined as the proposed Project boundary. Boott will develop the HPMP in consultation with the NPS, MHC, NHDHR, and Indian tribes.

Through this consultation, the Licensee will develop historic properties management measures to be incorporated into the HPMP. Boott has outlined the following two goals for managing historic resources within the Project's APE:

- Support continued normal operation of the Project while maintaining and preserving the integrity of historic properties; and
- To the fullest extent possible, avoid, minimize, or mitigate adverse effects on historic properties within the APE.

To address these goals, the Licensee will develop an HPMP for the Project in accordance with the *Guidelines for the Development of Historic Properties Management Plans for FERC Hydroelectric Projects* promulgated by FERC and the ACHP on May 20, 2002. The HPMP will describe measures for the management of and protection of historic properties within the Project's APE through the term of the new license. As such, continued operation of the Project as proposed by the Licensee is not expected to adversely affect historic or archaeological resources.

E.7.8.4 Unavoidable Adverse Impacts

The continued operation of the Project as proposed by the Licensee is not expected to have any unavoidable adverse effects on historic or archaeological resources.

E.8 Economic Analysis

This section identifies estimated costs specific to proposed PM&E measures. Overall Project cost and value information is provided in Exhibit D of the license application.

Proposed PM&E Measure	One Time Implementation/ Construction Costs (2021 Dollars)	Incremental Operations and Maintenance (O&M) Costs or Annual Costs (2021 Dollars)
ROR operation	$0 – (currently implemented)	$0
Modifications to upstream fish ladder and bypass weirs	$100,000	$5,000
Provide 100 cfs bypass flow aprrox. July 16 – April 30	$0	± 1,100 MWh / year lost generation
Upstream fish ladder	$2,600,000	$10,000
Cessation of fish elevator operations	$75,000	$0
Downstream rack structure	$5,200,000	$10,000
Develop and implement a Decommissioning Plan for each of the four downtown power stations and file for FERC approval.	$1,000,000	$0
Develop a Historic Properties Management Plan and file for FERC approval.	$75,000	$5,000
Develop a Recreation Access and Facilities Management Plan and file for FERC approval.	$50,000	$10,000

E.9 Consistency with Comprehensive Plans

Section 10(a)(2) of the FPA, 16 U.S.C. section 803(a)(2)(A), requires the Commission to consider the extent to which a project is consistent with federal and state comprehensive plans for improving, developing, or conserving a waterway or waterways affected by a project. Under 18 CFR §5.18(b)(5)(ii)(F) each license application must identify relevant comprehensive plans and explain how and why the proposed project would, would not, or should not comply with such plans. In addition, the license application must include a description of any relevant resource agency or Native American Tribe determination regarding the consistency of the project with any such comprehensive plan.

The Commission's SD2 identified twenty-eight comprehensive plans for New Hampshire and Massachusetts that are potentially relevant to the Lowell Hydroelectric Project. On December 19, 2018, the NPS filed five additional comprehensive plans, and by letter dated March 20, 2019, the Commission accepted four of the five plans. Boott has reviewed the Commission's list of the available comprehensive plans. Listed below are the comprehensive plans applicable to the Project. For the reasons noted in this application, Boott has determined that the proposed operation of the Project, as proposed in this Final License Application, is consistent with these plans.

E.9.1 Federal Plans

Atlantic States Marine Fisheries Commission. 1998. Amendment 1 to the Interstate Fishery Management Plan for Atlantic sturgeon (*Acipenser oxyrhynchus oxyrhynchus*). (Report No. 31). July 1998.

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Atlantic States Marine Fisheries Commission. 2008. Amendment 2 to the Interstate Fishery Management Plan for American eel. Arlington, Virginia. October 2008.

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E.9.2 Massachusetts Comprehensive Plans

Massachusetts Department of Environmental Management. n.d. Commonwealth connections: A greenway vision for Massachusetts. Boston, Massachusetts.

Massachusetts Department of Fish and Game. 2006. Comprehensive wildlife conservation strategy. West Boylston, Massachusetts. September 2006.

Massachusetts Executive Office of Energy and Environmental Affairs. Statewide Comprehensive Outdoor Recreation Plan (SCORP): Massachusetts Outdoor 2006. Boston, Massachusetts.

E.9.3 New Hampshire Comprehensive Plans

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.

New Hampshire Office of Energy and Planning. 2007. New Hampshire Statewide Comprehensive Outdoor Recreation Plan (SCORP): 2008-2013. Concord, New Hampshire. December 2007.

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

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

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

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E.10 Consultation Documentation

In accordance with 18 C.F.R § 5.18(b)(5)(G), a list of containing the name, and address of every Federal, state, and interstate resource agency, Indian tribe, and member of the public with which the Licensee consulted in preparation of Exhibit E is presented in Volume I. In addition, Boott is providing a consultation log of relevant correspondence with the contacts of the distribution list and copes of relevant documentation, presented in Appendix C.

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