Operation Analysis of the Lowell Canal Study

Lowell Hydroelectric Project (FERC No. 2790)

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Contents

1 Introduction and Background 1
1.1 Project Description and Background 1
2 Study Goals and Objectives 3
3 Study Area 3
4 Methodology 5
4.1 Literature Review 5
5 Study Results 5
5.1 Project Generating Units 5
5.2 Project Operations and Unit Dispatch Sequence 7
5.2.1 General Project Operations 7
5.2.2 Canal Unit Dispatch Sequence 7
5.2.3 Historical Canal Unit Operations 7
6 Summary and Discussion 9
7 Variances from FERC-Approved Study Plan 10

Tables

Table 5-1. Lowell Project Generating Unit Characteristics 6
Table 5-2. Percentage of Days Canal Units were Operated by Year (1998 – 2007) 8
Table 5-3. Percentage of Days Canal Units were Operated by Month (1998 – 2007) 8
Table 5-4. Number of Days Canal Units were Operated by Month and Year 9

Figures

Figure 3-1. Existing Project Boundary and Facilities of the Lowell Canal System 4

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List of Acronyms

Boott	Boott Hydropower, LLC (or Licensee)
CFR	Code of Federal Regulations
cfs	cubic feet per second
FERC	Federal Energy Regulatory Commission (or Commission)
ILP	Integrated Licensing Process
kW	kilowatt
MW	megawatt
NGVD 29	National Geodetic Vertical Datum of 1929
Project	Lowell Hydroelectric Project (or Lowell Project)
Proprietors	Proprietors of the Locks and Canals
RM	river mile
ROR	run-of-river
SPD	Study Plan Determination

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1 Introduction and Background

Boott Hydropower, LLC (Boott or Licensee) is the Licensee, owner, and operator of the 20.2-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 Project's existing license 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 (CFR) Part 5.

In accordance with 18 CFR §5.15, Boott has conducted studies as provided in the study plan and schedule approved in the Commission's March 13, 2019 Study Plan Determination (SPD) for the Project.[1] This report describes the methods and results of the approved Operation Analysis of the Lowell Canal Study.

1.1 Project Description and Background

The Lowell Project is located at river mile (RM) 41 on the Merrimack River in the City of Lowell in Middlesex County, Massachusetts, with an impoundment extending approximately 23 miles upstream into Hillsborough County, New Hampshire. 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 (E.L. Field) which uses water from the Northern Canal and contains two turbine-generator units with a total installed capacity of 15.0 MW;
5) A 440-foot-long tailrace channel;
6) Four powerhouses (Assets, Bridge Street, Hamilton, and John Street) housed in nineteenth century mill buildings along the Pawtucket, Hamilton, and Eastern canal systems containing 15 turbine-generator units with a total installed capacity of approximately 5.1 MW;

[1] The Commission issued a Revised Process Plan and Schedule on June 12, 2020.

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 E.L. Field powerhouse and a vertical-slot fish ladder at the Pawtucket Dam; and

9) Appurtenant facilities.

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 acres. The gross storage capacity between the normal surface elevation of 92.2 feet and the minimum pond level of 87.2 feet is approximately 3,600 acre-feet.

The Project operates in a run-of-river (ROR) mode using automatic pond level control capability of the E.L. Field Powerhouse and has no usable storage capacity. 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 (approximately 3,300 cubic feet-per-second [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 of the existing FERC license, the Project maintains a minimum flow of 1,990 cfs or inflow, whichever is less, as measured immediately downstream from the Project.

On December 2, 2020, Boott filed a Draft License Application (DLA) with the Commission pursuant to 18 CFR §5.16(a). As described in the DLA, Boott is proposing to remove the four canal power stations (Assets, Bridge Street, Hamilton, and John Street) and associated canal infrastructure from the new FERC license. Operation of the canal units is no longer economically feasible, and Boott is not proposing to continue generation at these four developments. 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 and other stakeholders.

2 Study Goals and Objectives

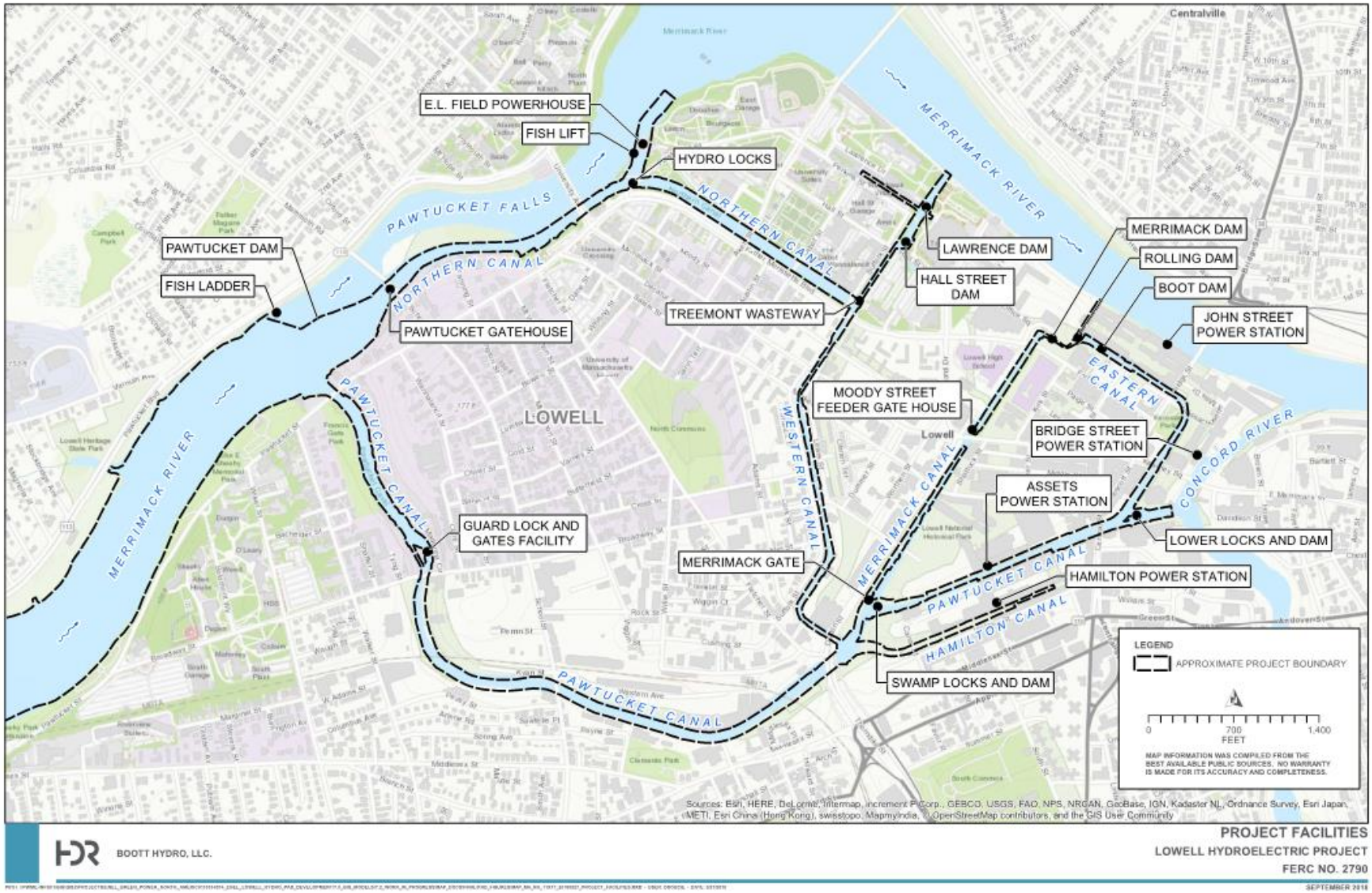
The goal of this study is to understand the operations of the Project's canal system. The specific objective of this study is to describe, to the extent possible, the operations of the canal system, which include, but are not limited to:

- How all of the canal units interact with the main units at the E.L. Field Powerhouse;
- How the canal units are sequenced;
- How often each of the canal units operate;
- The prioritization sequence of canal unit operations; and
- The amount of time the canal units are operated during the downstream passage season.

3 Study Area

The study area for the Operation Analysis of the Lowell Canal Study includes the Project's canal system and powerhouses located in the City of Lowell (Figure 3-1).

Figure 3-1. Existing Project Boundary and Facilities of the Lowell Canal System



4 Methodology

4.1 Literature Review

Boott conducted a desktop file review to examine current Project operational protocols and historical canal operations data. The canal units have experienced repeated maintenance issues, and generation is marginal, inefficient, and uneconomical under current conditions. Several of the canal system units have experienced prolonged outages in recent years, and the canal system as a whole has not been operated for purposes of generation in more than a year.

Historically, it has not been Boott's practice to log or otherwise record which of the individual canal units or powerhouses were in operation on a daily basis. As such, Boott does not have records of when individual canal powerhouses or units were operating. In general, operational data for the canal system is limited, and recent changes in both Project ownership and staffing have further compounded this issue.

To address the goals and objectives of this study, Boott reviewed data from a 10-year period of typical canal unit operations from 1998 – 2007. Data from this period was utilized in this analysis as it represented a relatively normal period of canal operations in which many (although not necessarily all) of the canal units were available for dispatch at Merrimack River flows in excess of 6,600 cfs capacity of the E.L. Field Powerhouse units. While the dataset does not indicate which specific units or powerhouses were operating, it does include aggregate records of generation (in kilowatts [kW]) for the downtown canal system recorded at 08:00 AM on a daily basis for the period of record. This data can be used to estimate how often canal units were operated on an annual basis and during downstream passage seasons. Because generation was reported in the aggregate, it is not possible to determine specifically which units or combination of units were in operation on a daily basis. Similarly, the dataset provides only a "snapshot" of daily generation at 08:00 AM; therefore, the data does not provide information on intra-daily changes in generation. However, Boott believes that this dataset provides a means of characterizing generation trends in the Project's canal system annually and for downstream passage seasons.

5 Study Results

5.1 Project Generating Units

At present, the Project includes a total of 17 generating units, including two units at the E.L. Field Powerhouse and 15 units at the downtown canal powerhouses. Generating unit characteristics are summarized in Table 5-1.

Table 5-1. Lowell Project Generating Unit Characteristics

Powerhouse	Unit #	Type	Size (Inches)	Speed (RPM)	Net Head (Feet)	Flow Rate (cfs)	Power (HP)	Power (kW)
E. L. Field	1	Fuji Horizontal Full Kaplan	152.4	120	39	3,300	11,540	7,506
E. L. Field	2	Fuji Horizontal Full Kaplan	152.4	120	39	3,300	11,540	7,506
Assets	1	Hercules Double Runner Styles C & D	33 and 31	150	13	376	444	265
Assets	2	Hercules Double Runner Styles C & D	33 and 31	150	13	376	444	265
Assets	3	Hercules Double Runner Styles C & D	33 and 31	150	13	376	444	265
Bridge Street	4	Hercules Type D Single Runner	42	138.5	22	333	655	360
Bridge Street	5	Hercules Type D Single Runner	42	138.5	22	333	655	360
Bridge Street	6	Hercules Type D Single Runner	42	138.5	22	333	655	360
Hamilton	1	Leffel Type Z Single Runner	45	120	13	374	459	280
Hamilton	2	Leffel Type Z Single Runner	39	133	13	279	341	190
Hamilton	3	Leffel Type Z Single Runner	36	150	13	237	287	160
Hamilton	4	Leffel Type Z Single Runner	45	120	13	374	459	280
Hamilton	5	Leffel Type Z Single Runner	45	120	13	374	459	280
John Street	3	Leffel Single Runner	33	200	21	250	482	300
John Street	4	Leffel Single Runner	33	200	21	250	482	300
John Street	5	Leffel Single Runner	33	200	21	250	482	300
John Street	6	Allis Chalmers Single Runner	72	100	21	1,000	1,925	1,200

5.2 Project Operations and Unit Dispatch Sequence

5.2.1 General Project Operations

As noted above, the Project operates in a ROR mode with no usable storage capacity. The two generating units at the E.L. Field Powerhouse are the most efficient units and are, therefore, the priority first-on, last-off units. It has been Boott's practice to dispatch the canal units when Merrimack River flows exceed the combined 6,600 cfs hydraulic capacity of the units at the E.L. Field Powerhouse. At flows higher than 6,600 cfs, Boott would typically divert up to 2,000 cfs to the canal units. Flows higher than 8,600 cfs (the combined capacity of the E.L. Field Powerhouse and the canal units) are spilled over the Pawtucket Dam spillway and into the Project's bypass reach.

5.2.2 Canal Unit Dispatch Sequence

In general, the canal unit dispatch sequence is intended to maximize the efficiency of units. Due to the imbalance of unit flow capacities between the units along the Hamilton Canal and the lower Pawtucket and Eastern canals, the Hamilton units would generally be the first units to be dispatched at Merrimack River flows in excess of 6,600 cfs. The Bridge Street units along the lower Pawtucket Canal and the John Street units along the Eastern Canal would then typically be sequenced to match the operating Hamilton canal units.

Notwithstanding this ideal unit dispatch sequence, Boott notes that the canal units have not been operated regularly in many years due to maintenance issues and other factors. In practice, the historical sequence for individual unit dispatch in each canal powerhouse has varied considerably depending on maintenance issues and unit operability. Historically, operators evaluated individual units based on flow conditions, operating efficiency, safety factors, and maintenance conditions prior to dispatching units for generation. As noted above, the canal units have not been operated in more than a year.

5.2.3 Historical Canal Unit Operations

As discussed in Section 4.1 of this study report, there is limited historical operations data available for the Project's existing downtown canal units. Boott analyzed aggregate canal unit generation data from a 10-year period of typical canal operations (1998 – 2007) to characterize operation of the Project's canal units. Boott also analyzed canal unit operations during the May – July fish passage season for spent alosines and the August – November fish passage season for adult eels and juvenile alosines. This analysis is indicative of the percent of time the canal units would be expected to operate each month under normal operating conditions.

Based on this analysis, the Project's canal units were operated on 34 percent of days during the total period of record (January 1, 1998 – December 31, 2007). The Project's canal units were operated on 40 percent of days during the May – July fish passage

season and on 15 percent of the days during the August – November fish passage season. Table 5-2 summarizes operation of the canal units by year.

Table 5-2. Percentage of Days Canal Units were Operated by Year (1998 – 2007)

Year	Total Annual Percentage of Days Canal Units were Operated	Percentage of Days Canal Units were Operated May – July	Percentage of Days Canal Units were Operated August – November
1998	37%	54%	1%
1999	30%	7%	19%
2000	30%	38%	2%
2001	17%	24%	0%
2002	27%	49%	3%
2003	40%	36%	37%
2004	45%	35%	30%
2005	64%	78%	48%
2006	29%	53%	7%
2007	18%	30%	8%

Boott also analyzed the operations of the Project's canal units on a monthly basis for the period of record, as shown in Table 5-3.

Table 5-3. Percentage of Days Canal Units were Operated by Month (1998 – 2007)

Month	Percentage of Days Canal Units were Operated
January	31%
February	23%
March	52%
April	81%
May	62%
June	43%
July	16%
August	6%
September	12%
October	15%
November	29%
December	35%

Finally, Boott conducted an analysis to determine the total number of days per month that the canal units were operated during the 10-year period of record, as shown in Table 5-4.

Table 5-4. Number of Days Canal Units were Operated by Month and Year

Month	Year									
	1998	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*
Jan	8	12	2	0	0	3	9	31	31	0
Feb	14	21	7	0	1	0	0	11	12	0
Mar	31	30	30	9	15	11	27	2	0	5
April	30	17	30	30	25	30	30	30	7	15
May	15	6	30	8	27	24	21	27	6	28
Jun	20	0	5	14	17	9	11	27	27	0
Jul	15	0	0	0	1	0	0	18	16	0
Aug	0	0	2	0	0	11	4	0	2	0
Sep	0	9	0	0	0	2	19	5	0	0
Oct	0	10	0	0	0	8	5	23	0	1
Nov	1	4	0	0	4	24	8	30	6	9
Dec	0	2	5	0	9	24	31	29	0	7

6 Summary and Discussion

The Lowell Project's canal generating units have experienced maintenance issues that have prevented normal operation of the units for the past several years. Limited operational data is available for the canal units, and it has not been Boott's practice to record individual canal unit or powerhouse start/stop times or daily generation. In order to address the goals and objectives of the Operation Analysis of the Lowell Canal Study, Boott reviewed available data from a period of relatively normal canal unit operations (1998 – 2007) to characterize how often the canal units were operated on an annual basis and during the May – July and August – November downstream fish passage seasons. Based on the available data, canal unit operations varied considerably from year-to-year. In general, this can be attributed to two primary factors:

- **Merrimack River Flows:** Boott prioritizes generation at the E.L. Field Powerhouse, and the downtown canal units are not dispatched until Merrimack River flows exceed the combined 6,600 cfs hydraulic capacity of the E.L. Field Powerhouse's two generation units;
- **Unit Maintenance and Operability:** The majority of the canal units were last upgraded in the 1940s and are now almost 80 years old. These units are routinely out-of-service for maintenance or because they are simply inoperable.

As discussed in Boott's December 2, 2020 DLA for the Project, operation of the canal units is no longer economically feasible, and Boott has proposed to remove the downtown developments (Assets, Bridge Street, Hamilton, and John Street) from the Project's FERC license. Boott is not proposing to restart or continue generation at these four developments.

7 Variances from FERC-Approved Study Plan

The Operation Analysis of the Lowell Canal Study was conducted in full accordance with the methods described in the FERC-approved study plan except for the following variances:

- The approved study plan directs Boott to describe how often each of the canal units operate and the amount of time canal units operate during the downstream passage season. As discussed in this study report, it has not been Boott's practice to record individual canal unit operations or document unit start/stop times. Accordingly, Boott reviewed and analyzed records from a period of relatively normal canal unit operations that reflect a daily "snapshot" of aggregate canal unit generation.