Relicensing Study 3.8.1

Evaluate the Impact of Current and Potential Future Modes of Operation on Flow, Water Elevation and Hydropower Generation

Study Report

Northfield Mountain Pumped Storage Project (No. 2485) and Turners Falls Hydroelectric Project (No. 1889)

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EXECUTIVE SUMMARY

FirstLight Hydro Generating Company (FirstLight) is the current licensee of the Northfield Mountain Pumped Storage Project (FERC No. 2485) and the Turners Falls Hydroelectric Project (FERC No. 1889). FirstLight has initiated with the Federal Energy Regulatory Commission (FERC, the Commission) the process of relicensing the two Projects using the FERC's Integrated Licensing Process (ILP). The current licenses for Northfield Mountain and Turners Falls Projects were issued on May 14, 1968 and May 5, 1980, respectively, with both set to expire on April 30, 2018. This report documents the results of Study No. 3.8.1 *Evaluate the Impact of Current and Potential Future Modes of Operations on Flow, Water Elevation and Hydropower Generation* (Operations Study).

The study plan developed and approved for this study contained three primary objectives: 1.) develop a baseline model of the mainstem Connecticut River from the Wilder Project to the Holyoke Project, 2.) use the model to determine the impact of potential alternative modes of operation on hydropower generation and economics, and 3.) use model results to inform other studies.

The study objectives were met by collecting data from various government agencies and hydropower generators for the development of an operations model. The model was first calibrated to generation and flows at the United States Geological Survey (USGS) on the Connecticut River at Montague, MA for calendar year 2002. A baseline model was subsequently developed to reflect today's operating equipment and today's operating requirements. Table E-1 provides a breakdown of the resulting total generation from the FirstLight Projects provided by the baseline run. There were no deviations from the study plan.

Table E-1: Power Generation for Baseline Run

Project	Station	Modeled Generation (MWh)
Northfield Mountain	Northfield Station	923,968
Turners Falls	Cabot Station	272,045
	Station No. 1	19,420
Total		**1,215,433**

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cfs	cubic feet per second
CRUISE	Connecticut River Unimpacted Streamflow Estimation
FERC	Federal Energy Regulatory Commission
FirstLight	FirstLight Hydro Generating Company
HEC-ResSim	Hydrologic Engineering Center Reservoir Simulation
ILP	Integrated Licensing Process
Operations Study	Study 3.8.1 – *Evaluate the Impact of Current and Potential Future Modes of Operation on Flow, Water Elevations, and Hydropower Generation*
PAD	Pre-Application Document
PSP	Proposed Study Plan
RSP	Revised Study Plan
SD1	Scoping Document 1
SD2	Scoping Document 2
SPDL	Study Plan Determination Letter
TFI	Turners Falls Impoundment
TNC	The Nature Conservancy
UMass	University of Massachusetts
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
VY	Vermont Yankee Nuclear Power Plant
WSEL	water surface elevation

1 INTRODUCTION

FirstLight Hydro Generating Company (FirstLight) is the current licensee of the Northfield Mountain Pumped Storage Project (FERC No. 2485) and the Turners Falls Hydroelectric Project (FERC No. 1889). FirstLight has initiated with the Federal Energy Regulatory Commission (FERC, the Commission) the process of relicensing the two Projects using the FERC's Integrated Licensing Process (ILP). The current licenses for Northfield Mountain and Turners Falls Projects were issued on May 14, 1968 and May 5, 1980, respectively, with both set to expire on April 30, 2018.

As part of the ILP, FERC conducted a public scoping process during which various resource issues were identified. On October 31, 2012, FirstLight filed its Pre-Application Document (PAD) and Notice of Intent with the FERC. The PAD included FirstLight's preliminary list of proposed studies. On December 21, 2012, FERC issued Scoping Document 1 (SD1) and preliminarily identified resource issues and concerns. On January 30 and 31, 2013, FERC held scoping meetings for the two Projects. FERC issued Scoping Document 2 (SD2) on April 15, 2013.

FirstLight filed its Proposed Study Plan (PSP) on April 15, 2013 and, per the Commission regulations, held a PSP meeting at the Northfield Visitors Center on May 14, 2013. Thereafter, FirstLight held ten resource-specific study plan meetings to allow for more detailed discussions on each PSP and on studies not being proposed. On June 28, 2013, FirstLight filed with the Commission an Updated PSP to reflect further changes to the PSP based on comments received at the meetings. On or before July 15, 2013, stakeholders filed written comments on the Updated PSP. FirstLight filed a Revised Study Plan (RSP) on August 14, 2013 with FERC addressing stakeholder comments.

On August 27, 2013 Entergy Corp. announced that the Vermont Yankee Nuclear Power Plant (VY), located on the downstream end of the Vernon Impoundment on the Connecticut River and upstream of the two Projects, will be closing no later than December 29, 2014. With the closure of VY, certain environmental baseline conditions will change during the relicensing study period. On September 13, 2013, FERC issued its first Study Plan Determination Letter (SPDL) in which many of the studies were approved or approved with FERC modification. However, due to the impending closure of VY, FERC did not act on 19 proposed or requested studies pertaining to aquatic resources. The SPDL for these 19 studies was deferred until after FERC held a technical meeting with stakeholders on November 25, 2013 regarding any necessary adjustments to the proposed and requested study designs and/or schedules due to the impending VY closure. FERC issued its second SPDL on the remaining 19 studies on February 21, 2014, approving the RSP with certain modifications.

This report contains the results of Study No. 3.8.1 - *Evaluate the Impact of Current and Potential Future Modes of Operation on Flow, Water Elevation, and Hydropower Generation* (Operations Study), which was completed through the development of an operations simulation model. The Operations Study was approved with modifications in the first SPDL (i.e. dated September 13, 2013). The lone modification was with regards to the evaluation of ramping rates, and allowed FirstLight to perform this assessment through either "the HEC-RAS modeling proposed in Study 3.2.2, or with a modified HEC-ResSim model" (FERC, 2013). FirstLight has determined that the evaluation of ramping rates is best performed with the HEC-RAS model, and thus will not be addressed in this report.

The specific goals and objectives of this study are:

- To develop a baseline model of the Connecticut River Basin – specifically the reach from the Wilder Project to the Holyoke Project – which includes the following hydropower facilities: TransCanada's Wilder, Bellow Falls, and Vernon Hydroelectric Projects, FirstLight's Turner Falls Hydroelectric Project and Northfield Mountain Project and Holyoke Gas and Electric's Holyoke Hydroelectric Project.

- The model will be used to determine the impact on hydropower generation and economics due to potential alternative modes of operation. Potential alternative modes of operation could include minimum flows in the bypass reach, changes in Turners Falls Impoundment (TFI) fluctuations, changes in operation of the Turners Falls Project relative to peaking operations, etc.

- Flow data generated from the model will be used to inform other studies, notably the hydraulic model and instream flow study.

Note: All figures and larger tables appear at the end of each Section.

2 SUMMARY OF DATA COLLECTION

Data collection efforts for model development and calibration include time series, engineering, and operations data as described below.

2.1 Time Series Data

The time series data collected includes observed and simulated datasets.

2.1.1 United States Geological Survey Data

Data used in this study from the United Stated Geological Survey (USGS) includes observed gage data and simulated data. The USGS maintains gages throughout the country, for which it estimates flow in cubic feet per second (cfs) based on rating curves (river stage versus flow) developed for each site. Table 2.1.1-1 lists the USGS Gages used in this study for either developing model inputs or comparison with model results as described in later sections of this report.

Table 2.1.1-1: USGS Gages used in Operations Study

Gage Number	Description
01161000	Ashuelot River at Hinsdale, NH
01166500	Millers River at Erving, MA
01170000	Deerfield River near West Deerfield, MA
01170500	Connecticut River at Montague City, MA

Simulated data from the USGS's Connecticut River Unimpacted Streamflow Estimation (CRUISE) model was also collected. The CRUISE model estimates daily unregulated flows (i.e. natural flows) utilizing basin-wide regression equations at 407 locations along the Connecticut River and its major tributaries (Archfield *et. al*., 2013). Using the CRUISE model, the USGS has developed daily flow data for the period of October 1, 1960 through September 30, 2012. Some of this flow data was used as inputs for the operations model as described in later sections of this report.

2.1.2 United States Army Corps of Engineers Data

Simulated flow data based on a model developed by the United States Army Corps of Engineers (USACE) was collected. This model estimates flow in the Connecticut River and its major tributaries using inflows from all 407 nodes of the USGS's CRUISE model along with engineering data for the many hydroelectric and flood control dams. The USACE simulated flows under existing operating conditions for the period of October 3, 1960 through September 27, 2012[1]. Some results from this model were used as inputs for the operations model as described in later sections of this report.

[1] The data originally provided by the USACE included simulation results for the period of January 1, 1961 through December 30, 2003. A new simulation results file was provided in August 2014 for the extended period of record. A review of this data raised concerns with its validity as some results do not correspond very well with historical USGS Gage records. For example, one location suggests a daily average peak flow (i.e.124,104 cfs) which is 20 times larger than the historical daily average peak flow (6,180 cfs). Therefore, the model currently uses the dataset originally provided by the USACE.

2.1.3 FirstLight Data

The FirstLight observed operations data collected for use in this study includes flows through pumps and turbines[2], water surface elevation (WSEL) in the TFI and Northfield Mountain Upper Reservoir, and power generation output. Some of these data were used as inputs for the operations model, while some were used during comparison of results as described in later sections of this report.

2.1.4 TransCanada Data

The observed total discharge from the Vernon Hydroelectric Project was provided by TransCanada for use in this study as an input during model calibration. The total discharge included flow through the turbines and flow passed via gates.

2.2 Engineering Data

The current applicable engineering data listed below was collected from both FirstLight and TransCanada for their respective hydropower projects on the Connecticut River mainstem. The following information is provided in Appendix A.

- Impoundment (e.g. stage-storage curves)
- Dam (e.g. elevation, tailwater rating curve)
- Power Plant(s) (e.g. minimum and maximum hydraulic capacity, generator capacity, overload factor)
- Pumps (e.g. hydraulic capacity)

2.3 Operations Data

The applicable operations data listed below was collected from both FirstLight and TransCanada for their respective hydropower projects on the Connecticut River mainstem. The following information is provided in Appendix B.

- Pool Fluctuation Limitations (e.g. minimum, maximum)
- Flow Release Limitations (e.g. minimum)

[2] In some cases flows were calculated using cfs vs MW rating curves; not direct measurement.

3 MODEL DEVELOPMENT

The development of an operations simulation model for the Operations Study began with the creation of a smaller model from an existing model (i.e. subset of existing model). This smaller model was then modified to achieve the goals and objectives of the Operations Study.

3.1 Existing Model

A partnership consisting of the Nature Conservancy (TNC), the USACE, the USGS, and the University of Massachusetts (UMass) at Amherst, developed a simulation model of the entire Connecticut River Basin using the USACE Hydrologic Engineering Center Reservoir System Simulation (HEC-ResSim) program[3]. The model includes all of the hydroelectric projects on the Connecticut River mainstem, as well as larger hydroelectric projects and flood control reservoirs on tributaries to the Connecticut River. It is a substantial model covering the entire geographic area of the basin on a daily time step for the period 1960 to 2003. The flow data for the model was developed by the USGS in Northborough, MA. FirstLight and TNC reached an agreement whereby TNC provided FirstLight with the USACE's HEC-ResSim model in exchange for FirstLight's engineering data on the Turners Falls Project and Northfield Mountain Project, as the existing model lacked detailed engineering data on FirstLight's Projects. The existing model will herein be referred to as the USACE model.

3.2 Model Modifications

Using the USACE model, a smaller model was developed for the Operations Study (i.e. a subset of the USACE model), which will herein be referred to as the FirstLight model. The FirstLight model includes the Connecticut River mainstem extending from the upper of the three TransCanada Projects (i.e. Wilder)[4] down to the Holyoke Project (FERC No. 2004), as indicated in Figure 3.2-1. The following sections detail additional changes made to the FirstLight Model for the purposes of the Operations Study.

3.2.1 Physical Data Inputs

The USACE model incorrectly defined the Northfield Mountain Project as an inline reservoir (i.e. dam on the Connecticut River). Therefore, the FirstLight model was modified to correctly simulate the Northfield Mountain Project as an offline reservoir with pump/turbine units to transfer water between the Upper Reservoir (i.e. offline reservoir) and the Lower Reservoir (i.e. TFI along the Connecticut River). Similarly, the FirstLight model was modified to more accurately represent the distribution of flows between the Turners Falls Dam and the Power Canal. Therefore a reservoir to represent the Power Canal was added which accounts for discharge from Cabot Station, Station No. 1, fish attraction and ladder structures, Turners Falls Hydro and Paperlogic.

Due to the FirstLight model operating on an hourly time step, the distribution of routing was also adjusted from how it was set up in the USACE model. The USACE model only applied variable lag streamflow routing to one reach within the study area of the FirstLight model (i.e. just upstream of the Vernon Project). This rather large lag time was instead distributed to several locations as presented in Table 3.2.1-1. The values of Lag and K for locations 3a through 3d were based on FirstLight operating procedures (i.e. Appendix B of the 1972 document titled "*Reservoir and River Flow Management Procedures*"), which estimates the travel time for flow between the Vernon and Turners Falls Projects as presented in Table

[3] HEC-ResSim is a software program designed to model reservoir operations at one or more reservoirs where operations are defined by a variety of operational goals and constraints. The software program was developed by the USACE's Hydrologic Engineering Center in Davis, CA and is publicly available from the USACE.

[4] The three TransCanada Projects in upstream to downstream order include: Wilder (FERC No. 1892), Bellows Falls (FERC No. 1855), and Vernon (FERC No. 1904, located immediately upstream of the Turners Falls Impoundment).

3.2.1-2. According to these FirstLight operating procedures, flow entering from the Ashuelot River takes 80% of the travel time, and flow entering from the Millers River takes 40% of the travel time compared to flow discharged from the Vernon Project.

Table 3.2.1-1: Variable Lag Streamflow Routing Locations

Location	Description	Lag/K Values
1	Just Upstream of Bellows Falls Project	8
2	Just Upstream of Vernon Project	4
3a	Just Upstream of Confluence with Ashuelot River	Varies (20% of Table 3.2.2-2)
3b	Just Upstream of Confluence with Pauchaug Brook	Varies (20% of Table 3.2.2-2)
3c	Just Upstream of Northfield Mountain Tailrace	Varies (20% of Table 3.2.2-2)
3d	Just Downstream of Confluence with Millers River	Varies (40% of Table 3.2.2-2)

Table 3.2.1-2: Streamflow Routing through the TFI

Flow (cfs)	Lag/K Values
0	10.0
13,000	10.0
14,000	9.5
15,000	9.0
17,000	8.5
19,000	8.0
22,000	7.5
25,000	7.0
30,000	6.5
36,000	6.0
42,000	5.5
51,000	5.0
63,000	4.5
77,000	4.0
108,000	3.5
170,000	3.0

3.2.2 Engineering and Operations Data Inputs

After reviewing the USACE model, it was noted that detail of the TransCanada and FirstLight Projects was lacking. Therefore an agreement was reached between FirstLight and TransCanada to exchange engineering and operations data for each company's hydropower projects. The FirstLight model was modified to incorporate the engineering and operations data for the TransCanada and FirstLight hydroelectric projects.

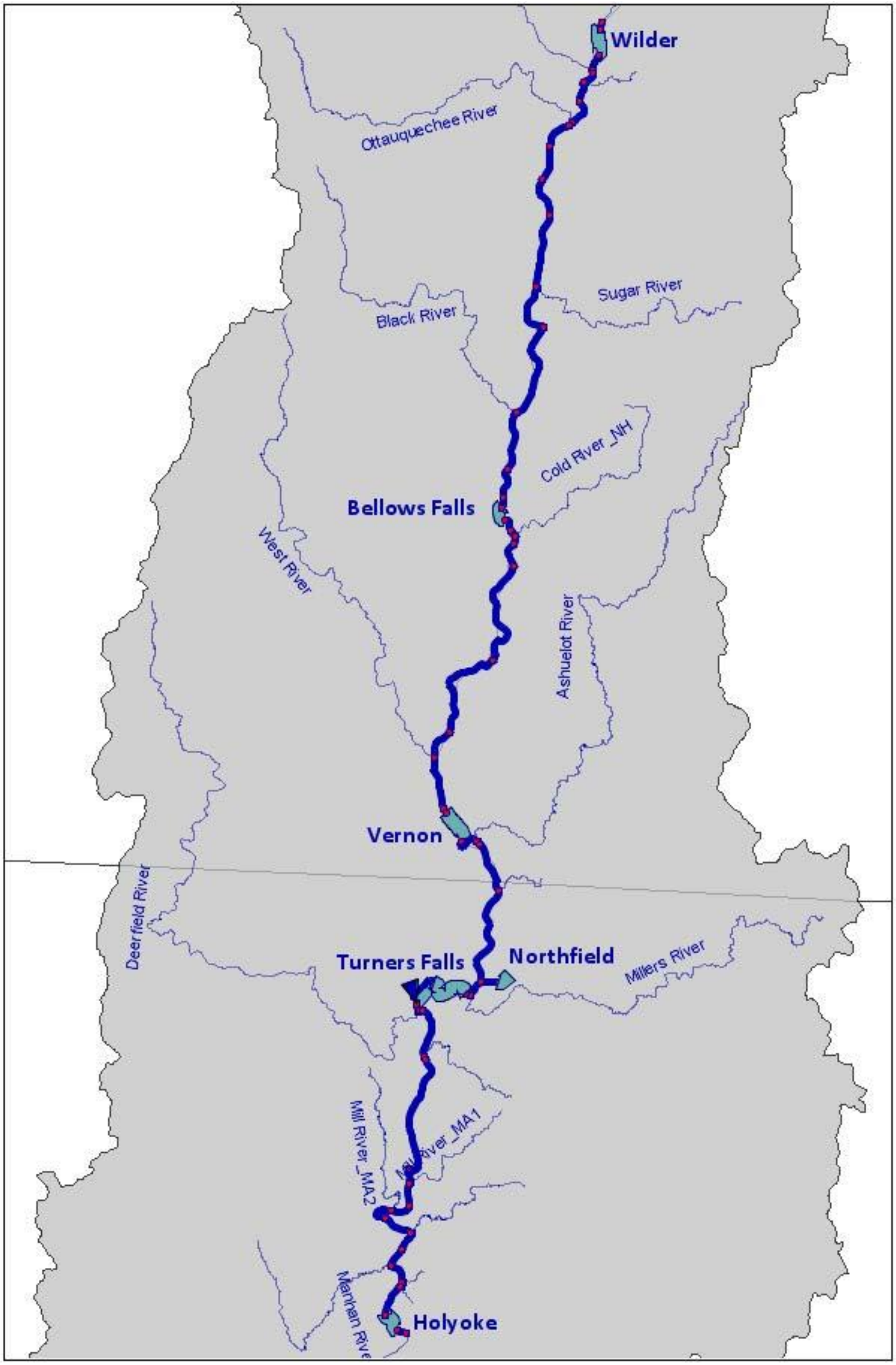

Figure 3.2-1: FirstLight Model Overview

4 MODEL RUNS

The previous section identified adjustments to the FirstLight model which apply to all runs performed for the Operations Study. This section will further identify the inputs and parameters which differed for each run.

4.1 Calibration Settings

A flow duration curve was developed using the observed flows (i.e. between 1975 and 2015) from the USGS Gage at Montague. This flow duration curve was used to help identify an appropriate year for calibration purposes. Calendar year 2002 was selected for the calibration run because a) it fell within the period of record of currently available CRUISE and USACE flow data (i.e. 1961-2011)[5], b) the flow duration curve for this year is generally representative of the period of record at Montague (see Figure 4.1-1)[6], and c) it is more likely to be representative of current operations (i.e. being more recent). In addition to the annual flow duration curve, we have included monthly flow duration curves as shown in Figures 4.1-2 (Jan, Feb, Mar), 4.1-3 (Apr, May, June), 4.1-4 (Jul, Aug, Sep) and 4.1-5 (Oct, Nov, Dec). As can be seen from these monthly flow durations the spring runoff for 2002 is fairly representative of the period of record (i.e. as indicated by April and May), while 2002 was a rather dry summer (i.e. as indicated by August and September).

The calibration run attempted to use as much observed data as possible to verify that the scripts used to simulate the Turners Falls and Northfield Mountain Projects were appropriate. Therefore, the portions of the FirstLight model upstream of and including the Vernon Project were disconnected, and the observed discharges from the Vernon Project were used as flow inputs. Additionally, the observed flows at the USGS Gages on the Ashuelot, Millers, and Deerfield Rivers were used as flow inputs. The observed flows from the USGS Gages on the Ashuelot and Millers Rivers were prorated to account for the entire drainage area between the Vernon and Turners Falls Projects. Thus all other flow data inputs locations between the Vernon and Turners Falls Projects (i.e. cumulative local inflow locations and tributaries inflow locations) were set to zero for the calibration run. The observed flow from the USGS Gage on the Deerfield was prorated to account for the additional drainage area between the gage and the mouth of the Deerfield River (i.e. at the confluence of the Deerfield and Connecticut Rivers) and the remaining small drainage areas between the Turners Falls Dam and the Montague USGS Gage. The remaining flow data inputs (i.e. downstream of the Turners Falls Project) consist of a combination of CRUISE model results and USACE model results. All inflows at cumulative local flow locations along the Connecticut River mainstem were defined using results from the CRUISE model, while all inflows from major tributaries were defined using results from the USACE model. The CRUISE and USACE models produce daily flow outputs, however, the FirstLight model was modified to support an hourly time step. As such, the daily flow outputs from the CRUISE and USACE models were converted to an hourly time step using straight line interpolation.

The units at Cabot Station of the Turners Falls Project were upgraded between 2001 and 2004, while the units at the Northfield Mountain Project were upgraded between 2004 and 2016. Therefore, the unit capacity and unit efficiencies utilized for the calibration run were defined to be consistent with the units installed during the 2002 calendar year. Additionally, the observed pumping and generation schedule from 2002 was used to define the operations at the Northfield Mountain Project for the calibration run. Finally, the Turners Falls Project was operated to try to maintain a total storage in the TFI and the Northfield

[5] Due to the potential issues with the USACE data discussed in Section 2.1.2, the true period of record currently available for calibration is 1960 through 2003.

[6] While the USGS Gage at Montague provides daily flows starting in 1903, the period of record used for this analysis begins in 1975 due changes in the regulation of the Connecticut River Basin (e.g. construction of flood storage facilities, implementation of minimum flow requirements).

Mountain Upper Reservoir which exceeds the storage capacity of the Northfield Mountain Upper Reservoir between its FERC allowable operating limits. The excess storage is termed the reservoir imbalance, and is used in the FirstLight model to define the TFI guide curve (i.e. target TFI WSEL). The average reservoir imbalance observed during each month of 2002 was used for the calibration run. It should be noted that the FirstLight model includes a reservoir imbalance adjustment based on TFI WSELs (i.e. to better match the WSEL duration curve for Turners Falls), as well as a reservoir imbalance adjustment for the time of day (i.e. to better match peaking operations).

4.2 Baseline Settings

The baseline run utilizes flow inputs from the 2002 calendar year for the same reasons presented for the calibration run, however, the baseline run uses a different geographic extent and different data sources for some of the flow inputs. The baseline run considers the full FirstLight model (i.e. includes the Wilder, Bellows Falls, and Vernon Projects), and utilized a combination of CRUISE model results and USACE model results for all of its flow data input locations. All inflows at cumulative local flow locations along the Connecticut River mainstem were defined using results from the CRUISE model, while all inflows from major tributaries were defined using results from the USACE model. These flow inputs were again converted to an hourly time step (i.e. from a daily time step) using straight line interpolation.

The baseline run utilizes the current (i.e. upgraded) unit capacity and efficiency values for the Turners Falls and Northfield Mountain Projects. The observed pumping and generation schedule from 2009 (i.e. as opposed to 2002) was used to define the operations at the Northfield Mountain Project for the baseline run, because it is considered more representative of current operations. These changes to the Northfield Mountain Project operations appear to have impacted the average monthly reservoir imbalance for the Turners Falls Project. Therefore, the average monthly reservoir imbalance used for the baseline run is based on data from 2012 to 2016. The baseline also slight altered the hourly adjustments to the reservoir imbalance from the values used for the calibration run.

4.3 Production Settings

The term production run refers to making modifications to the baseline model to reflect a new operating regime. For example, a production run could consist of simulating a higher minimum flow in the bypass channel. To date, no production runs have been made, but should FirstLight enter into settlement discussions with stakeholders, it would be making production runs. It should be noted that changes to the FirstLight model, necessary for completing potential future production runs, could require that the calibration and baseline runs be reanalyzed.

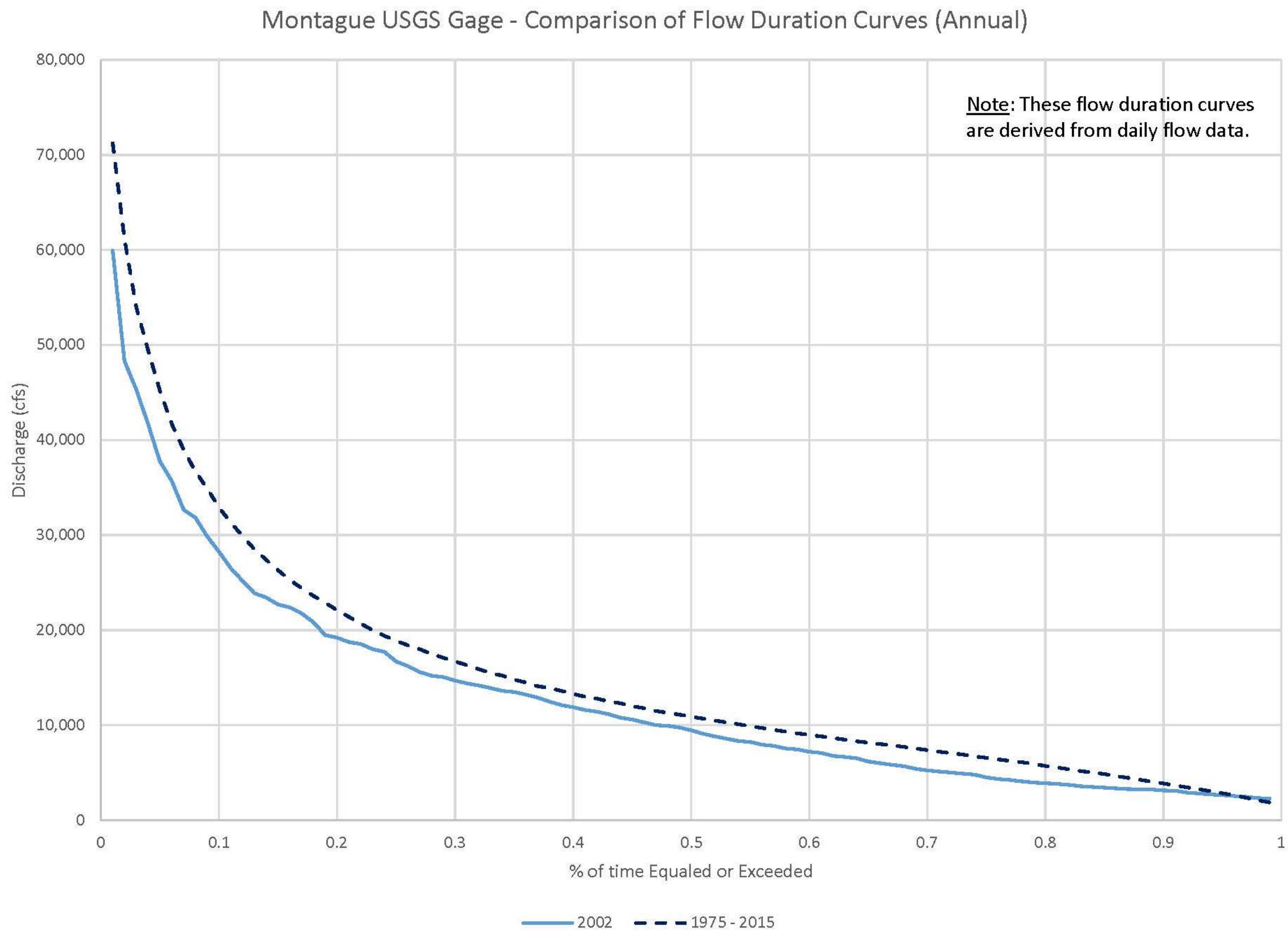

Figure 4.1-1: Flow Duration Curve Comparison at Montague (Annual)

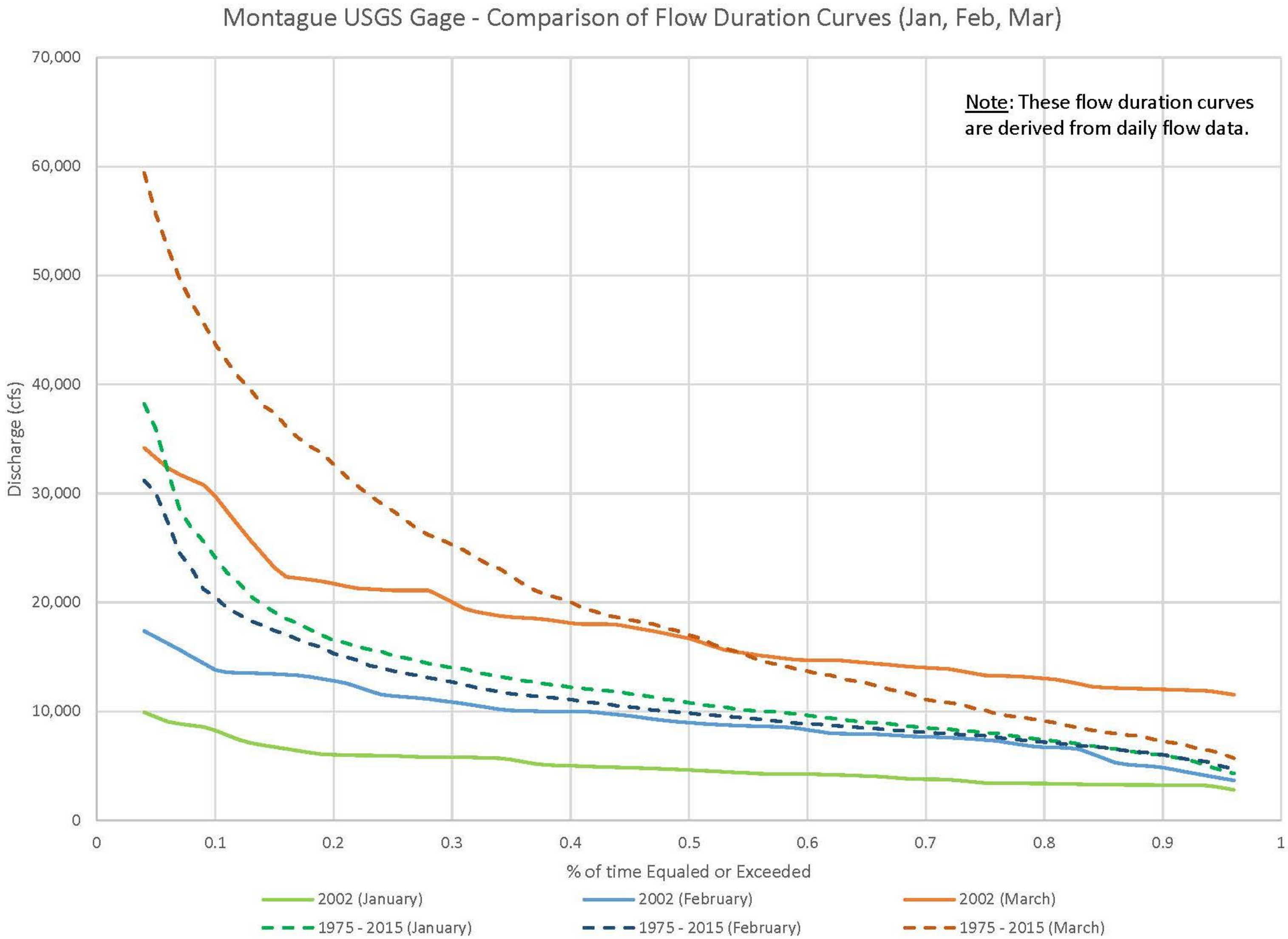

Figure 4.1-2: Flow Duration Curve Comparison at Montague (Jan, Feb, Mar)

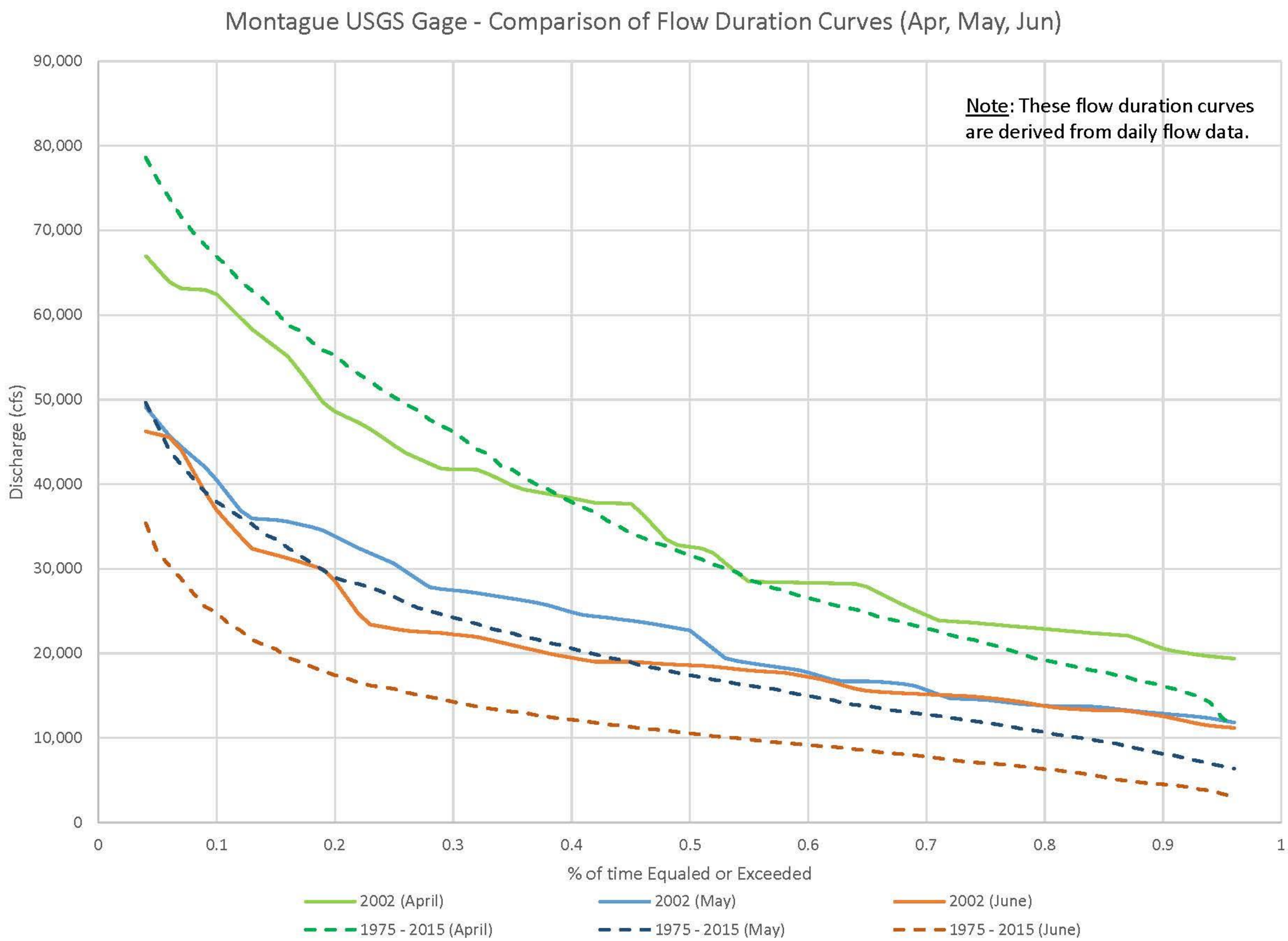

Figure 4.1-3: Flow Duration Curve Comparison at Montague (Apr, May, Jun)

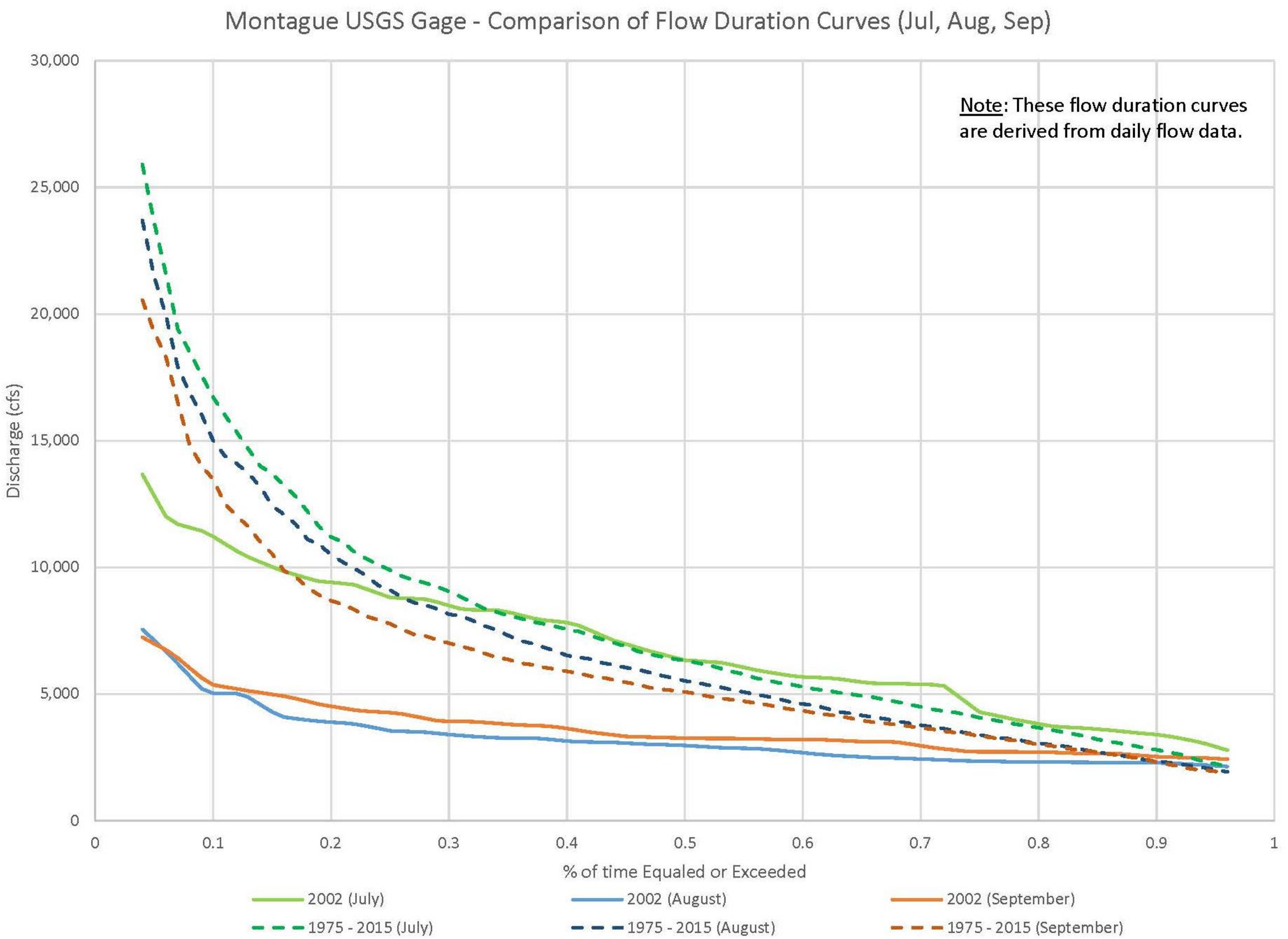

Figure 4.1-4: Flow Duration Curve Comparison at Montague (Jul, Aug, Sep)

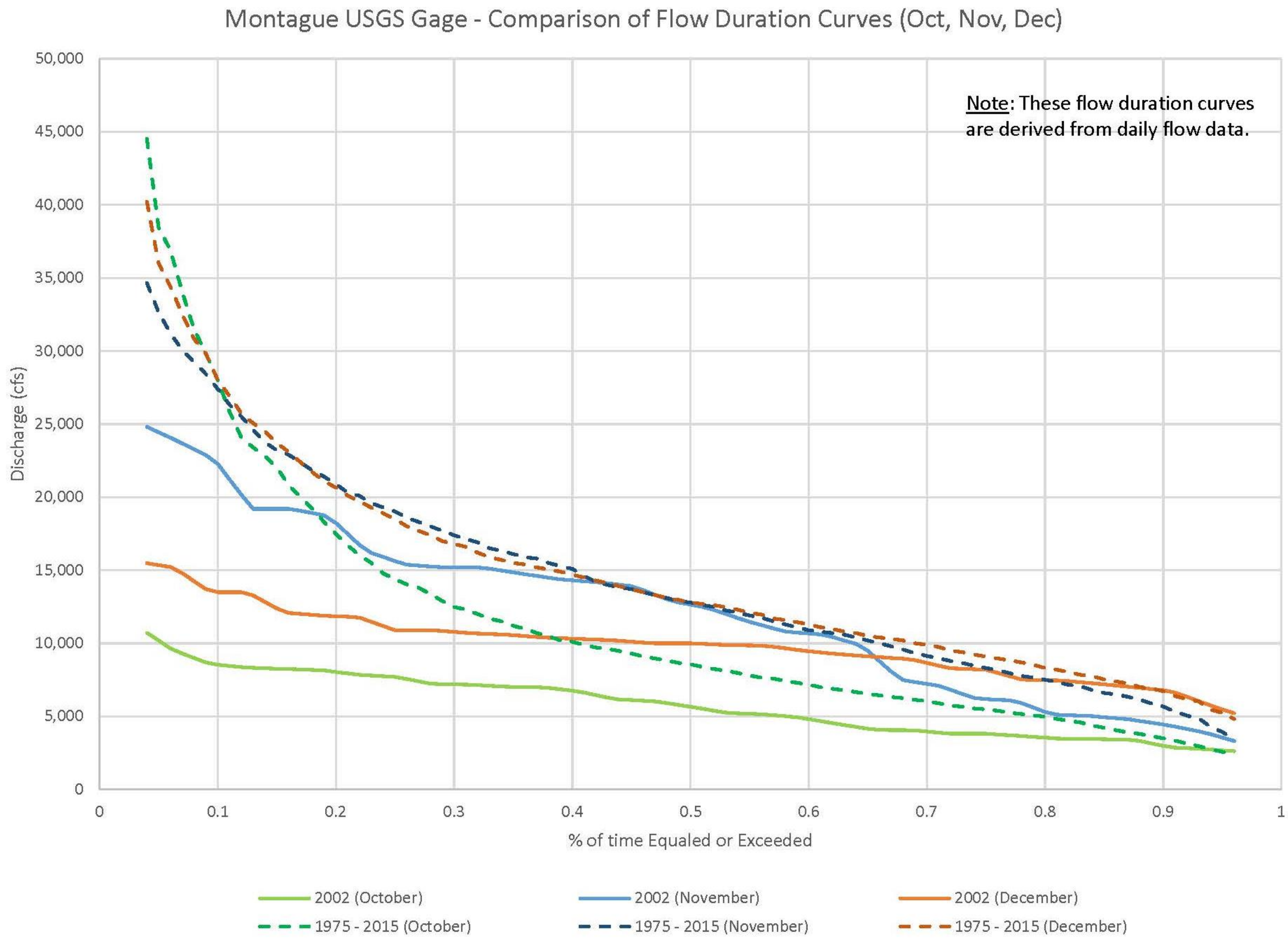

Figure 4.1-5: Flow Duration Curve Comparison at Montague (Oct, Nov, Dec)

5 MODEL RESULTS

5.1 Calibration Results

The calibration run met all minimum flow requirements for the Turners Falls Project, and stayed within the range of the TFI and Northfield Mountain Upper Reservoir WSELs observed during 2002. Figure 5.1-1 provides a comparison of the observed and modeled water elevation elevations curves of the TFI as measured at the Turners Falls Dam. The WSEL duration curve is generally within 0.2 ft, other than at the extremes (i.e. less than 10% exceedance and greater than 99% exceedance) which indicates a good match. Figure 5.1-2 provides a comparison of the observed and modeled flow duration curves at the Montague USGS Gage.

The magnitude and timing of generation also matched rather well, as shown in Table 5.1-1, as well as Figure 5.1-3 (Cabot Station) and Figure 5.1-4 (Station No. 1). While the observed vs modeled total generation at Station No. 1 does not match as well as at Northfield or Cabot, Station No. 1 is not a major contributor to the overall generation at the Northfield Mountain and Turners Falls Projects. Shown in Figure 5.1-5 is a comparison of the observed and modeled flow at the Montague USGS Gage. While the timing of generation does not exactly match the observed timing, the calibration run reasonably simulates the peaking operations.

Table 5.1-1: Comparison of Power Generation for Calibration Run

Project	Station	Observed Generation (MWh/yr)	Modeled Generation (MWh/yr)	Difference (%)
Northfield Mountain	Northfield Station	1,327,953	1,294,774	-2.5%
Turners Falls	Cabot Station	228,123	242,179	+6.2%
	Station No. 1	23,368	19,730	-15.6%
Total		**1,579,444**	**1,556,682**	**-1.4%**

It should be noted that changes to the FirstLight model necessary for completing potential future production runs could have slight implications for the calibration results.

5.2 Baseline Results

The baseline run met all minimum flow requirements for the Turners Falls Project. Figure 5.2-1 provides a comparison of the TFI exceedance elevations for observed and baseline conditions. The minimum and maximum exceedance curves are composite curves based on the exceedance curves for each year between 2000 and 2016. The baseline exceedance curve is higher than expected starting around the 18% exceedance mark, which is a little higher than the results from the calibration run (i.e. approximately 12%). It should be noted that the modeled TFI WSELs are still within the FERC allowable range 176 to 185 (ft NGVD 1929) as measured at the Turners Falls Dam. Table 5.2-1 provides the magnitude of generation for the baseline run. This table does not include a comparison, because it combines hydrology, unit capacities, and Northfield Mountain operations from different years. Figures 5.2-2, 5.2-3, and 5.2-4 indicate that the baseline run still does a reasonable job of simulating the timing of generation for peaking operations.

Table 5.2-1: Power Generation for Baseline Run

Project	Station	Modeled Generation (MWh/yr)
Northfield Mountain	Northfield Station	923,968
Turners Falls	Cabot Station	272,045
	Station No. 1	19,420
Total		**1,215,433**

It should be noted that changes to the FirstLight model necessary for completing potential future production runs, could have slight implications for the baseline results.

5.3 Production Results

No production runs have been completed to date. The FirstLight model will be used to determine the effect of potential modified operations on generation, WSELs, and flows. The FirstLight model may also be used as the licensing process moves forward to address stakeholder comments on other studies. Such studies may include but are not limited to:

- Study 3.1.2: Northfield Mountain/Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability
- Study 3.2.2: Hydraulic Study of Turners Falls Impoundment, Bypass Reach and below Cabot Station
- Study 3.3.1: Conduct Instream Flow Habitat Assessments in the Bypass Reach and Below Cabot Station

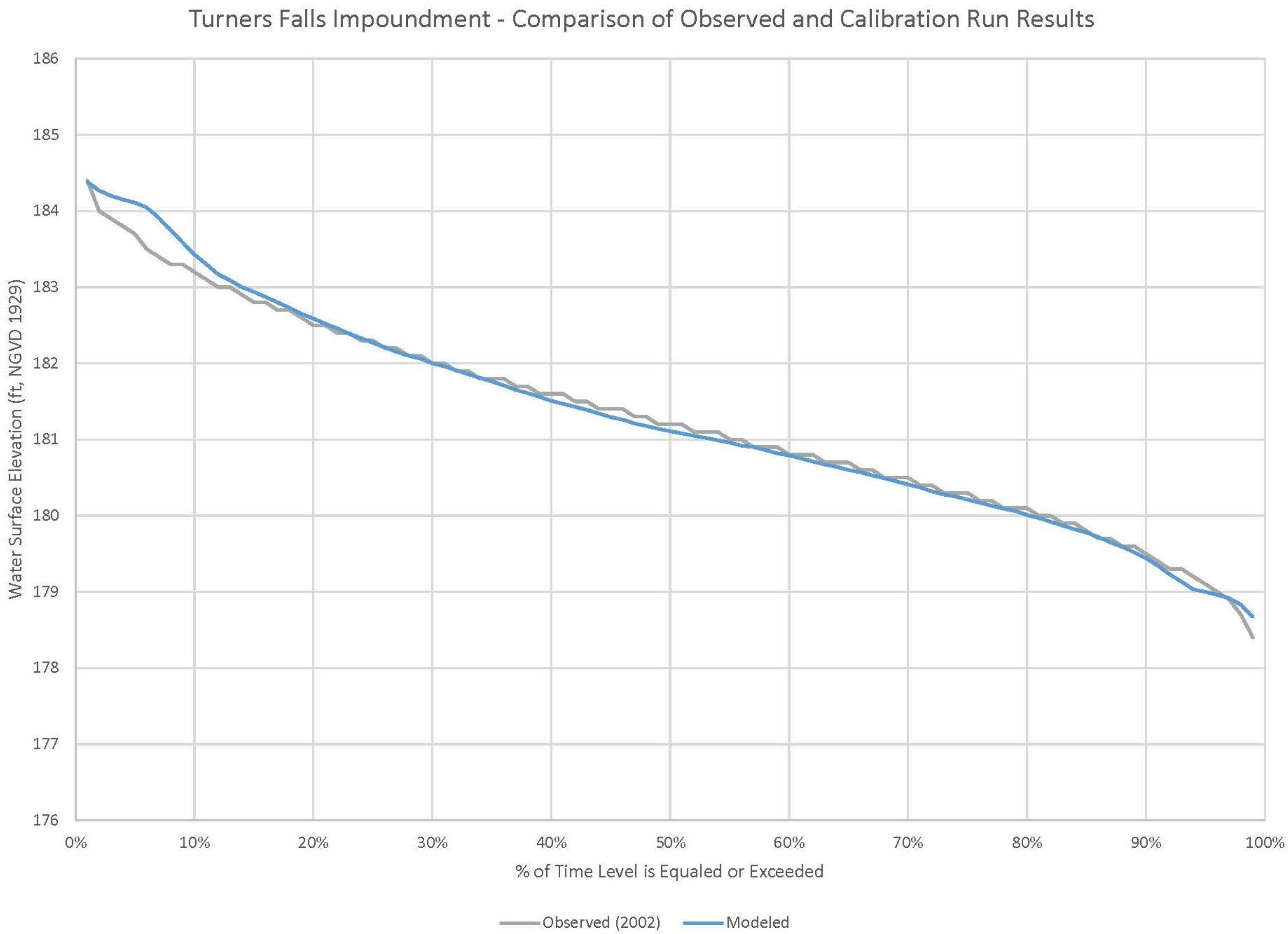

Figure 5.1-1: Turners Falls Impoundment (Calibration Run)

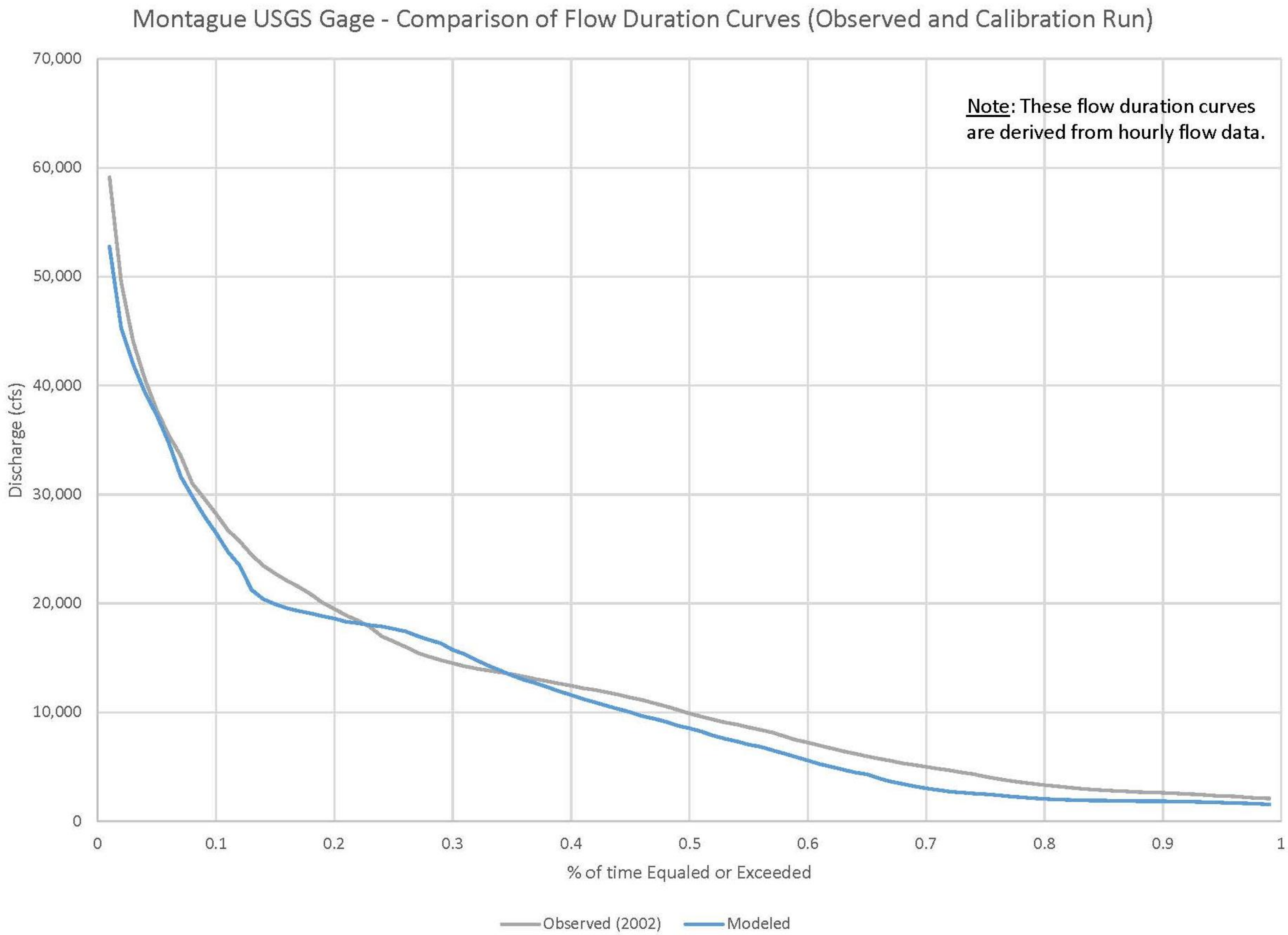

Figure 5.1-2: Montague USGS Gage Duration Curve (Calibration Run)

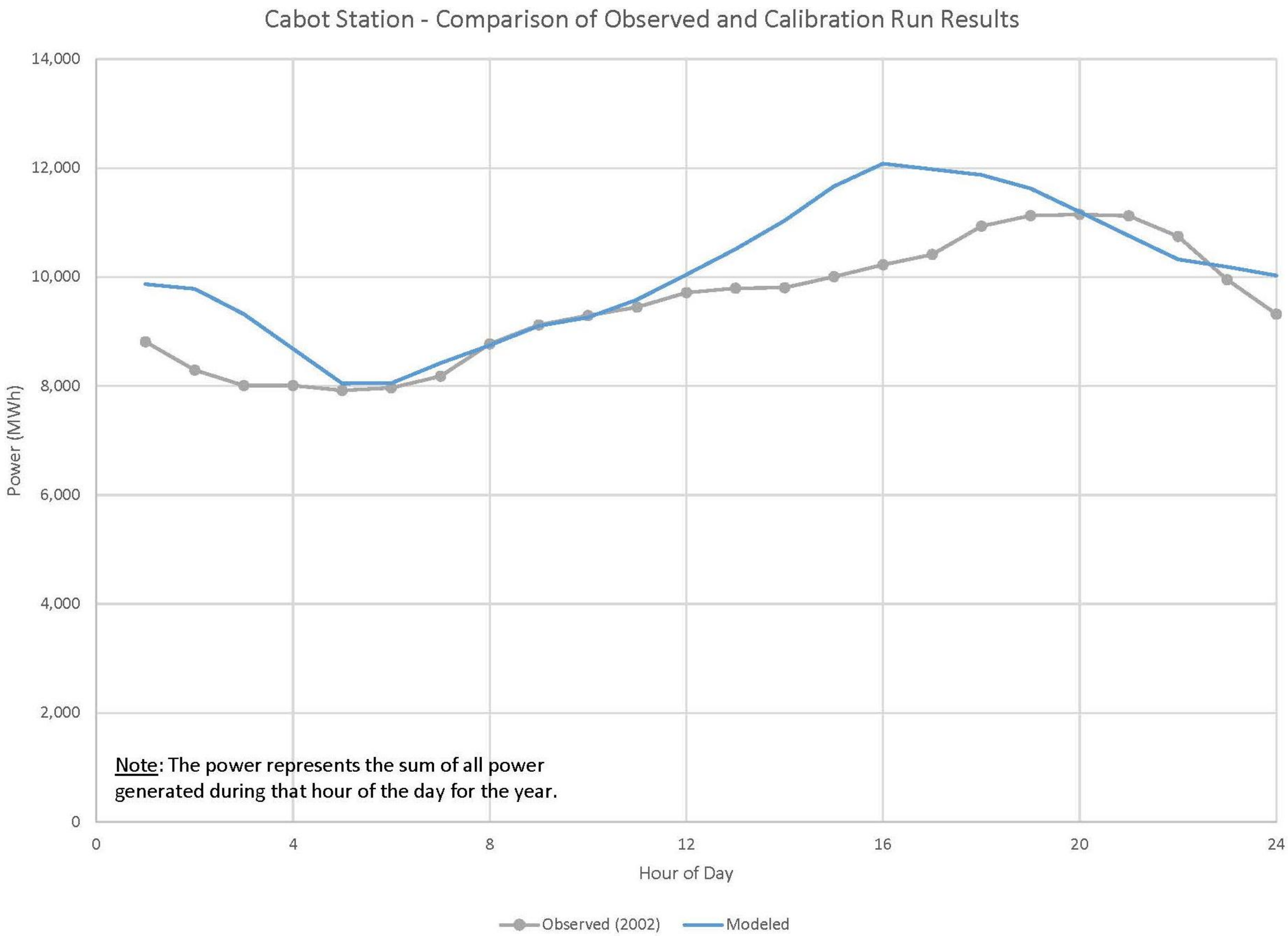

Figure 5.1-3: Cabot Station (Calibration Run)

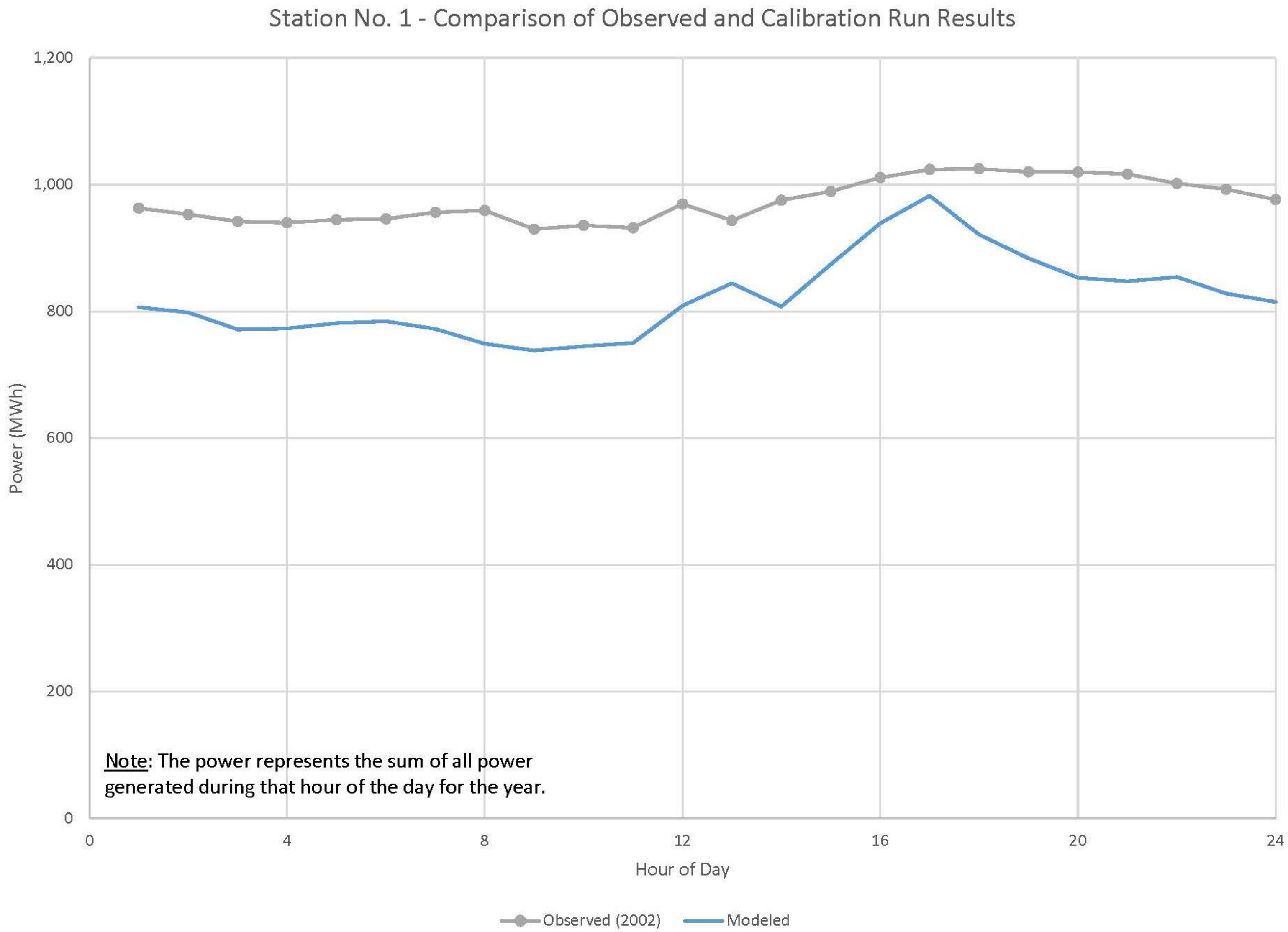

Figure 5.1-4: Station No. 1 (Calibration Run)

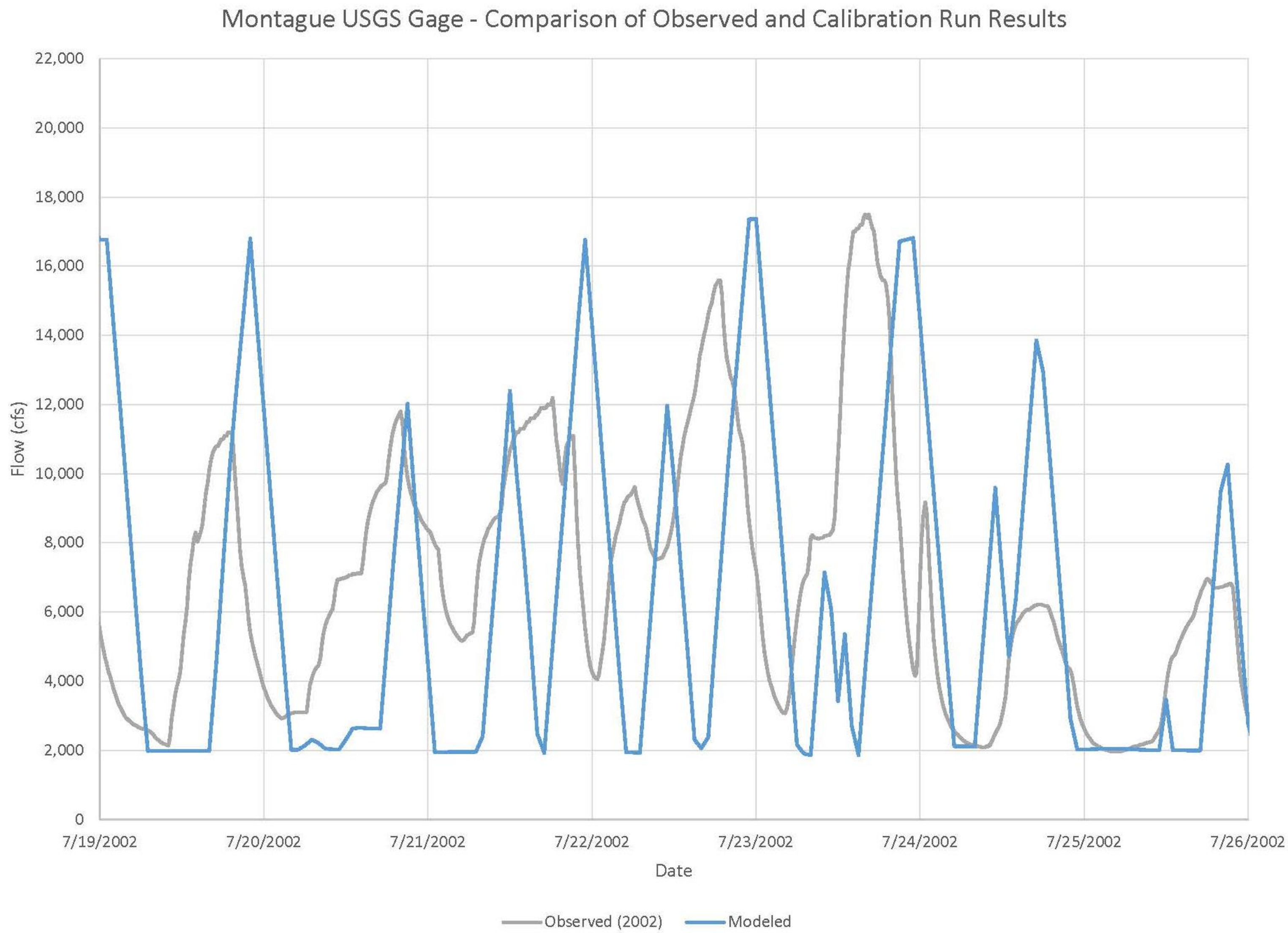

Figure 5.1-5: Montague USGS Gage (Calibration Run)

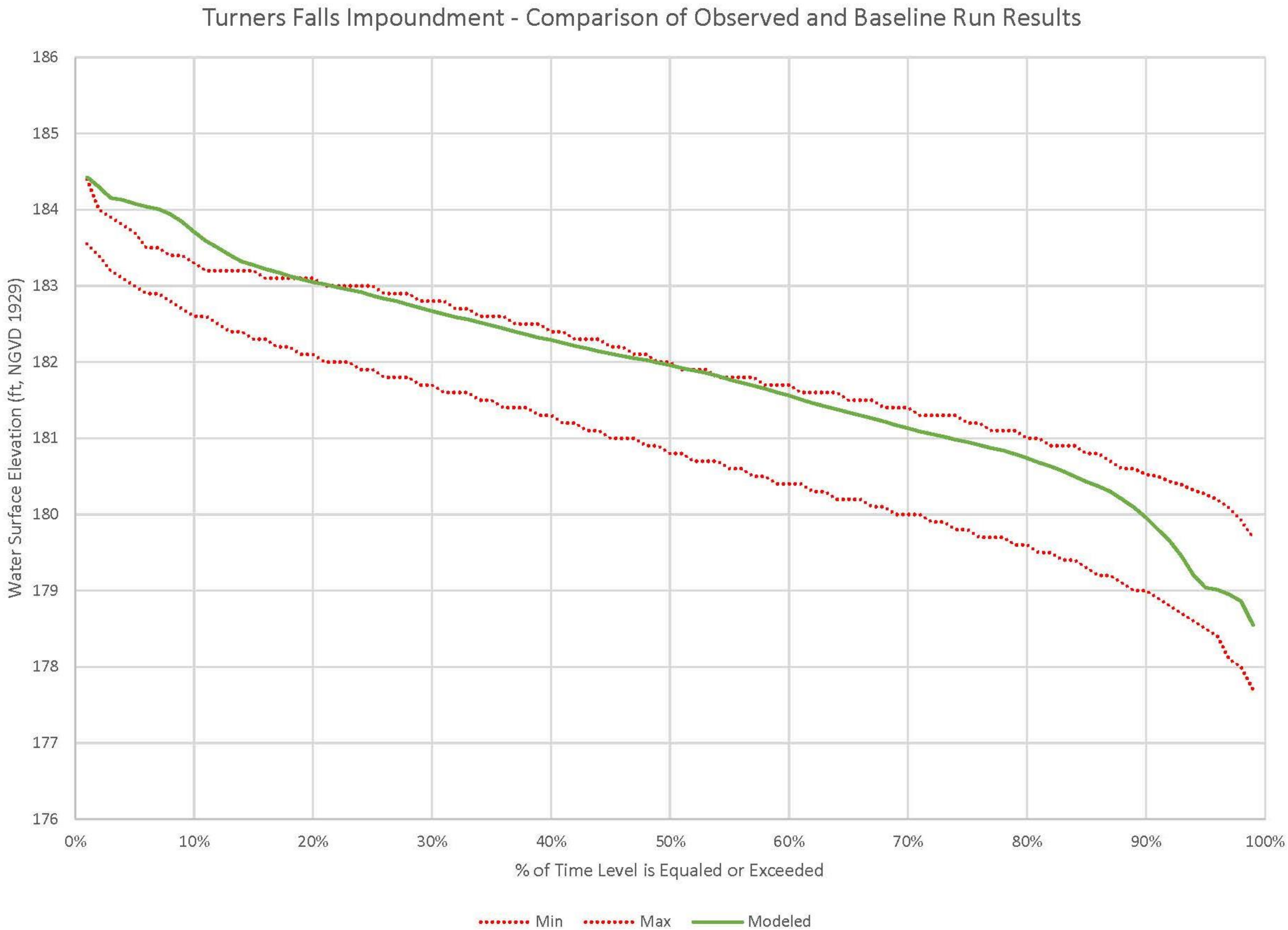

Figure 5.2-1: Turners Falls Impoundment (Baseline Run)

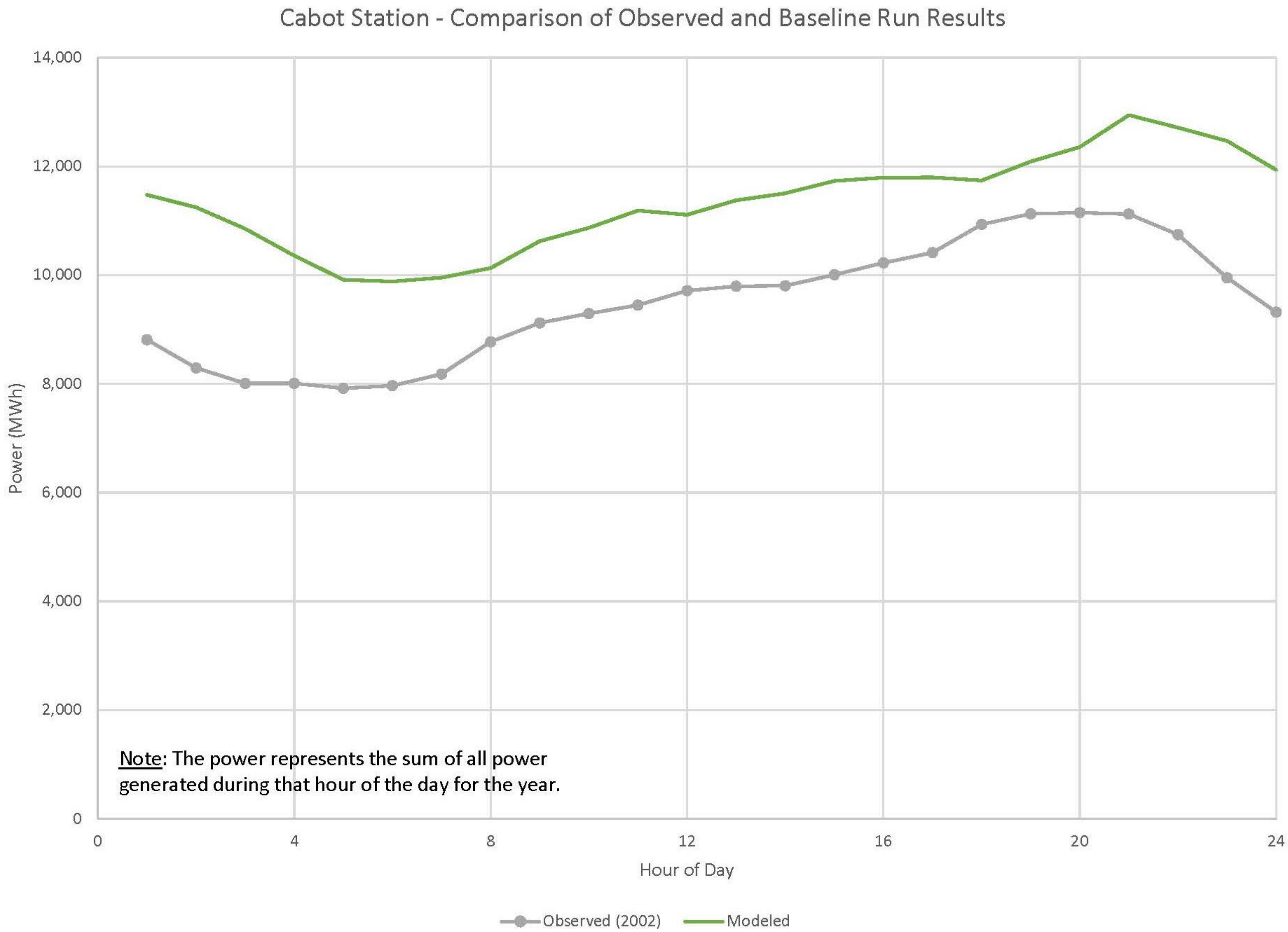

Figure 5.2-2: Cabot Station (Baseline Run)

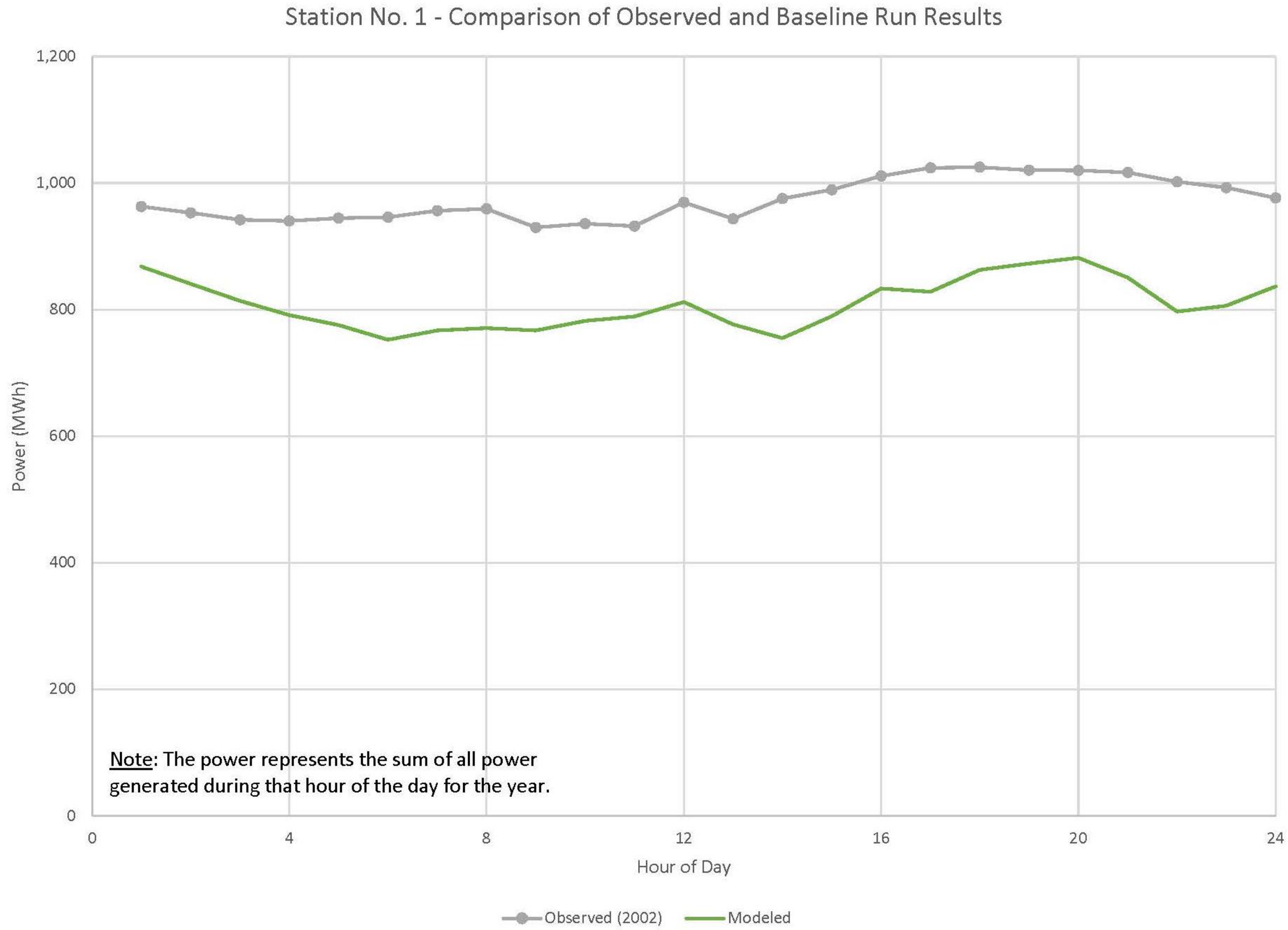

Figure 5.2-3: Station No. 1 (Baseline Run)

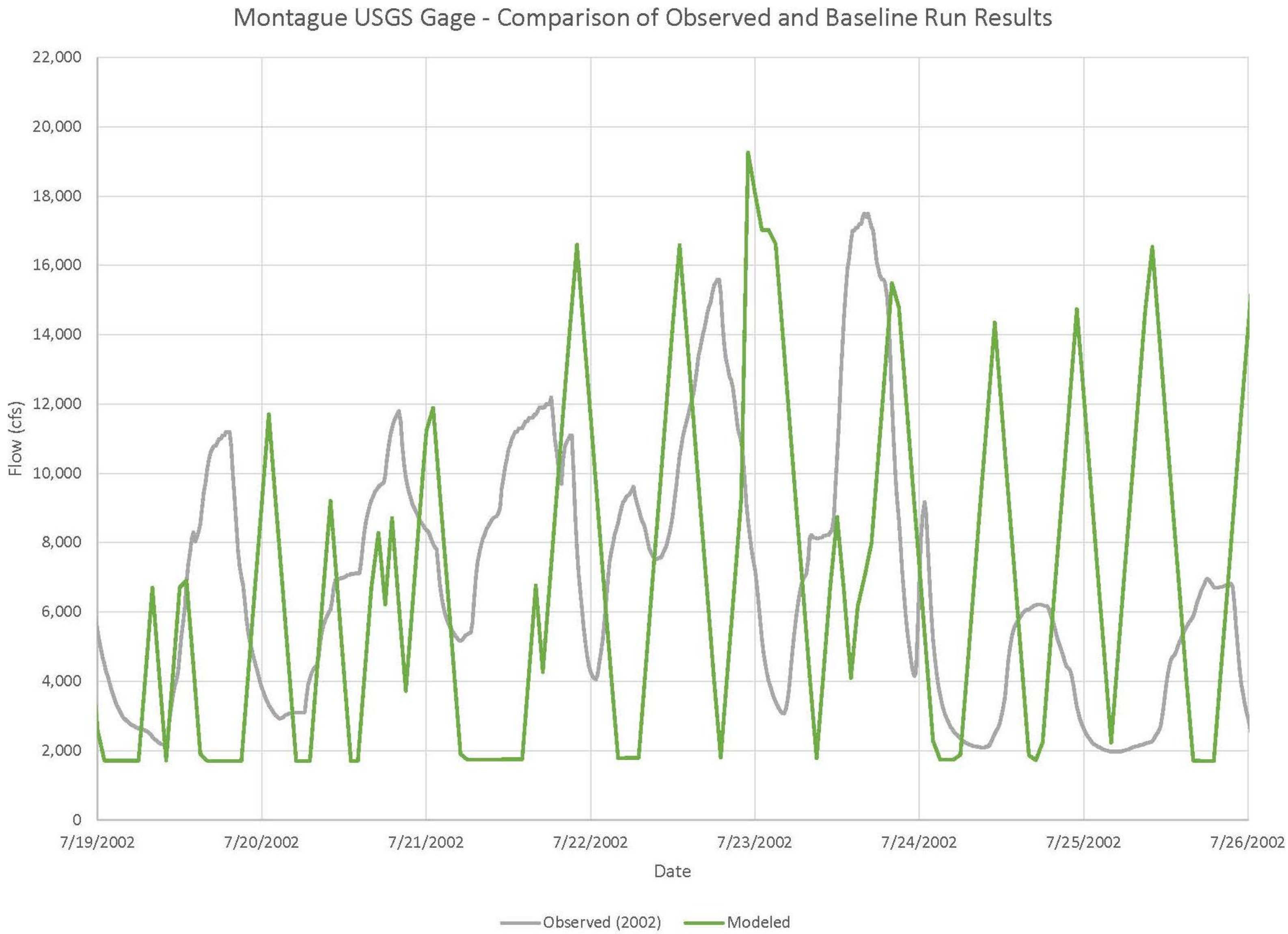

Figure 5.2-4: Montague USGS Gage (Baseline Run)

6 DISCUSSION

The USACE model was modified as appropriate in the creation of the FirstLight model to better simulate the operations of the Turners Falls and Northfield Mountain Projects. As part of these modifications additional information was collected with regards to the TransCanada Projects (i.e. Wilder, Bellows Falls, and Vernon) for incorporation into the model. A calibration run was performed with the FirstLight model using observed information from calendar year 2002. This calibration run provided acceptable agreement in TFI WSELs, as well as timing of and total generation output. Slight modifications were made from the calibration run for the purposes of defining a baseline run, which better represents current operations. The results of the baseline run were found to be similar to the results expected from current operations.

7 REFERENCES

Archfield, S. A., P. A. Steeves, J. D. Guthrie, and K. G. Ries III. (2013). Towards a publicly available, map-based regional software tool to estimate unregulated daily streamflow at ungauged rivers. Geoscientific Model Development, 6, 101–115.

Wright, J. (2013) "Federal Energy Regulatory Commission Study Plan Determination Letter for the Turners Falls Hydroelectric Project and the Northfield Mountain Pumped Storage Project." Letter to FirstLight. 13 Sept. 2013.

FirstLight Hydro Generating Company. (2013). Revised Study Plan for the Turners Falls Hydroelectric Project (No. 1889) and Northfield Mountain Pumped Storage Project (No. 2485). Northfield, MA.

United States Geological Survey Gages:

Ashuelot River at Hinsdale, NH (Gage No. 01161000)
http://waterdata.usgs.gov/nwis/inventory/?site_no=01161000

Millers River at Erving, MA (Gage No. 01166500)
http://waterdata.usgs.gov/nwis/inventory/?site_no=01166500

Deerfield River near West Deerfield, MA (Gage No. 01170000)
http://waterdata.usgs.gov/nwis/inventory/?site_no=01170000

Connecticut River at Montague City, MA (Gage No. 01170500)
http://waterdata.usgs.gov/nwis/inventory/?site_no=01170500

APPENDIX A – ENGINEERING DATA

Wilder Project

Elevation at Top of Dam: 393.0 ft

Generation Facilities

Capacity (MW)	Overload Factor	Hydraulic Capacity (cfs)	
		Minimum	Maximum
35.6	1.1	400	12,125

Stage-Storage Curve

Stage (ft)	Storage (acre-ft)
355	0
356	106
357	224
358	354
359	496
360	650
361	822
362	1,015
363	1,235
364	1,475
365	1,740
366	2,025
367	2,505
368	3,255
369	4,175
370	5,225
371	6,360
372	7,585
373	8,900
374	10,305
375	11,800
376	13,410
377	15,160
378	17,050
379	19,080
380	21,250
381	23,575
382	26,075
383	28,745
384	31,585
385	34,600

Tailwater Rating Curve

Stage (ft)	Flow (cfs)
327.5	0
327.7	700
331.9	12,700
349.0	62,600
355.4	94,000
358.0	108,000
364.0	135,000

Bellows Falls Project

Elevation at Top of Dam: 305.5 ft

Generation Facilities

Capacity (MW)	Overload Factor	Hydraulic Capacity (cfs)	
		Minimum	Maximum
40.8	1.1	700	11,550

Stage-Storage Curve

Stage (ft)	Storage (ac-ft)
283.6	10,633
283.7	10,773
283.8	10,913
283.9	11,054
284.0	11,194
284.1	11,334
284.2	11,482
284.3	11,630
284.4	11,778
284.5	11,926
284.6	12,074
284.7	12,230
284.8	12,385
284.9	12,541
285.0	12,696
285.1	12,852
285.2	13,015
285.3	13,179
285.4	13,342
285.5	13,506
285.6	13,669
285.7	13,840
285.8	14,011
285.9	14,182
286.0	14,353
286.1	14,524
286.2	14,703
286.3	14,882
286.4	15,060
286.5	15,239
286.6	15,418
286.7	15,605
286.8	15,792
286.9	15,979
287.0	16,166
287.1	16,353
287.2	16,549

Stage-Storage Curve (Continued)

Stage (ft)	Storage (ac-ft)
287.3	16,745
287.4	16,940
287.5	17,136
287.6	17,332
287.7	17,537
287.8	17,742
287.9	17,946
288.0	18,151
288.1	18,356
288.2	18,570
288.3	18,783
288.4	18,997
288.5	19,210
288.6	19,424
288.7	19,647
288.8	19,870
288.9	20,094
289.0	20,317
289.1	20,540
289.2	20,774
289.3	21,007
289.4	21,241
289.5	21,474
289.6	21,708
289.7	21,952
289.8	22,196
289.9	22,440
290.0	22,684
290.1	22,928
290.2	23,183
290.3	23,437
290.4	23,691
290.5	23,945
290.6	24,200
290.7	24,465
290.8	24,730
290.9	24,994

Stage-Storage Curve (Continued)

Stage (ft)	Storage (ac-ft)
291.0	25,259
291.1	25,524
291.2	25,799
291.3	26,074
291.4	26,350
291.5	26,625
291.6	26,900

Tailwater Rating Curve

Stage (ft)	Flow (cfs)
225.63	0
226.63	500
226.80	1,300
227.63	5,000
228.63	9,900
228.70	11,010
230.63	29,900
233.63	54,900
237.63	94,900

Vernon Project

Elevation at Top of Dam: 228.0 ft

Generation Facilities

Capacity (MW)	Overload Factor	Hydraulic Capacity (cfs)	
		Minimum	Maximum
32.4	1.1	1,600	17,130

Stage-Storage Curve

Stage (ft)	Storage (ac-ft)
212.1	0
212.2	200
212.3	400
212.4	600
212.5	800
212.6	1,000
212.7	1,205
212.8	1,410
212.9	1,615
213.0	1,820
213.1	2,025
213.2	2,235
213.3	2,444
213.4	2,654
213.5	2,864
213.6	3,073
213.7	3,287
213.8	3,500
213.9	3,714
214.0	3,926
214.1	4,140
214.2	4,358
214.3	4,575
214.4	4,792
214.5	5,009
214.6	5,226
214.7	5,447
214.8	5,668
214.9	5,889
215.0	6,110
215.1	6,330
215.2	6,555
215.3	6,779
215.4	7,003
215.5	7,227
215.6	7,452
215.7	7,679
215.8	7,907
215.9	8,135
216.0	8,362

Stage-Storage Curve (Continued)

Stage (ft)	Storage (ac-ft)
216.1	8,590
216.2	8,821
216.3	9,052
216.4	9,283
216.5	9,514
216.6	9,745
216.7	9,980
216.8	10,214
216.9	10,449
217.0	10,683
217.1	10,918
217.2	11,155
217.3	11,393
217.4	11,631
217.5	11,869
217.6	12,107
217.7	12,348
217.8	12,588
217.9	12,830
218.0	13,071
218.1	13,312
218.2	13,556
218.3	13,800
218.4	14,044
218.5	14,288
218.6	14,533
218.7	14,780
218.8	15,027
218.9	15,275
219.0	15,522
219.1	15,769
219.2	16,020
219.3	16,270
219.4	16,521
219.5	16,771
219.6	17,021
219.7	17,275
219.8	17,529
219.9	17,782
220.0	18,036

Stage-Storage Curve (Continued)

Stage (ft)	Storage (ac-ft)
220.1	18,289
220.2	18,545
220.3	18,802
220.4	19,058
220.5	19,315
220.6	19,571
220.7	19,831
220.8	20,090
220.9	20,350
221.0	20,609
221.1	20,869
221.2	21,131
221.3	21,393
221.4	21,656
221.5	21,918
221.6	22,181
221.7	22,446
221.8	22,711
221.9	22,976
222.0	23,241
222.1	23,507

Tailwater Rating Curve

Stage (ft)	Flow (cfs)
181.5	0
181.7	1,600
182.0	4,500
185.4	12,634
186.0	14,000
187.0	19,000
194.0	44,000
198.5	64,000

Northfield Mountain Project

Elevation at Top of Dam: 1,010 ft

Generation Facilities

Capacity (MW)	Overload Factor	Hydraulic Capacity (cfs)	
		Minimum	Maximum
1,166.6	0	2,500	20,000

Stage-Storage Curve

Stage (ft)	Storage (ac-ft)
920.0	0
921.0	88
922.0	177
923.0	269
924.0	363
925.0	459
926.0	558
927.0	658
928.0	760
929.0	865
930.0	972
931.0	1,081
932.0	1,192
933.0	1,306
934.0	1,422
935.0	1,540
936.0	1,660
937.0	1,781
938.0	1,905
939.0	2,030
940.0	2,157
941.0	2,286
942.0	2,417
943.0	2,550
944.0	2,685
945.0	2,823
946.0	2,962
947.0	3,101
948.0	3,244
949.0	3,387
950.0	3,532
951.0	3,678
952.0	3,827
953.0	3,976
954.0	4,128
955.0	4,281
956.0	4,436
957.0	4,593
958.0	4,752
959.0	4,912

Stage-Storage Curve (Continued)

Stage (ft)	Storage (ac-ft)
960.0	5,077
961.0	5,248
962.0	5,425
963.0	5,597
964.0	5,775
965.0	5,956
966.0	6,141
967.0	6,328
968.0	6,519
969.0	6,713
970.0	6,910
971.0	7,110
972.0	7,314
973.0	7,520
974.0	7,729
975.0	7,940
976.0	8,155
977.0	8,374
978.0	8,596
979.0	8,820
980.0	9,046
981.0	9,276
982.0	9,508
983.0	9,743
984.0	9,980
985.0	10,221
986.0	10,464
987.0	10,710
988.0	10,958
989.0	11,208
990.0	11,461
991.0	11,751
992.0	11,971
993.0	12,229
994.0	12,489
995.0	12,750
996.0	13,014
997.0	13,280
998.0	13,547
999.0	13,816

Stage-Storage Curve (Continued)

Stage (ft)	Storage (ac-ft)
1000.0	14,087
1000.5	14,223
1001.0	14,360
1002.0	14,633
1003.0	14,969
1004.0	15,187
1004.5	15,327

Pumping Facilities

Operating Head (ft)	Pump Capacity (cfs)
759.00	3,700.00
765.00	3,650.00
771.00	3,600.00
778.00	3,550.00
784.00	3,500.00
790.00	3,450.00
796.00	3,400.00
804.00	3,350.00
810.00	3,300.00
815.00	3,250.00
822.00	3,200.00
826.00	3,150.00
832.00	3,100.00
835.00	3,050.00
840.00	3,000.00

Turners Falls Project

Elevation at Top of Dam: 200.0 ft

Generation Facilities

Station	Capacity (MW)	Overload Factor	Hydraulic Capacity (cfs)	
			Minimum	Maximum
Station No. 1	5.693	1.15	112	2,210
Cabot	62.016	0	1,400	13,728

Stage-Storage Curve

Stage (ft)	Storage (acre-ft)
172.26	0
176.00	4,150
177.00	5,600
178.00	7,500
179.00	9,200
180.00	11,100
181.00	13,000
182.00	14,750
183.00	16,600
184.00	18,450
185.00	20,200
186.00	22,100
186.50	23,000

Tailwater Rating Curve (at Dam)

Stage (ft)	Flow (cfs)
135.00	0
136.00	500
136.75	1,000
137.15	1,500
137.50	2,000
138.00	3,000
138.40	4,000
138.70	5,000
139.30	7,500
139.75	10,000
140.60	15,000
141.10	18,000
143.05	30,000
145.45	45,000
149.10	70,000
153.00	100,000
159.20	150,000
165.35	200,000
171.30	250,000

Tailwater Rating Curve (at Cabot)

Stage (ft)	Flow (cfs)
107.5	0
108.2	1,400
108.5	2,000
109.0	3,000
109.5	4,000
110.0	5,000
110.5	6,000
111.0	7,000
111.5	8,000
112.0	9,000
112.5	10,000
115.0	20,000
117.0	30,000
123.5	50,000
133.0	100,000
140.5	150,000
148.0	200,000
153.5	250,000

Tailwater Rating Curve (at Station No. 1)

Stage (ft)	Flow (cfs)
129.50	0
129.54	1,892
129.60	5,000
129.70	10,000
129.90	15,000
130.05	20,000
130.20	25,000
131.00	35,000
132.30	50,000
139.00	100,000
148.20	170,000
155.00	250,000

Holyoke Project

Elevation at Top of Dam: 117.8 ft

Generation Facilities

Capacity (MW)	Overload Factor	Hydraulic Capacity (cfs)	
		Minimum	Maximum
30	1.1	-	14,250

Stage-Storage Curve

Stage (ft)	Storage (acre-ft)
97.47	0
99.47	4,580
100.67	7,025

Tailwater Rating Curve (at Dam)

Stage (ft)	Flow (cfs)
68.0	0
76.0	112,000
77.5	158,000
78.3	180,000
80.3	242,000

APPENDIX B – OPERATIONS DATA

Wilder Project

FERC Normal Operating Limits: 380.0 ft to 385.0 ft

Minimum Flow Requirements

	Required Flow on Given Start Date (cfs)						
	01-Jan	01-Apr	15-May	16-Jun	16-Jul	15-Sep	16-Nov
- Fish Ladder	-	-	25	25	-	25	-
- Downstream Fish Passage	-	512	512	-	-	-	-
- Aquatic Habitat Requirement	675	675	675	675	675	675	675
Minimum Project Flow[1] (i.e. greatest of above)	**675**	**675**	**675**	**675**	**675**	**675**	**675**

Notes:

1. Minimum flow requirements can be reduced no lower than the total project inflow.

Bellows Falls Project

FERC Normal Operating Limits: 288.6 ft to 291.6 ft

Minimum Flow Requirements

	Required Flow on Given Start Date (cfs)						
	01-Jan	01-Apr	15-May	16-Jun	16-Jul	15-Sep	16-Nov
- Fish Ladder	-	-	80	80	-	80	-
- Downstream Fish Passage	-	255	255	-	-	-	-
- Aquatic Habitat Requirement	1,083	1,083	1,083	1,083	1,083	1,083	1,083
Minimum Project Flow[1] (i.e. greatest of above)	**1,083**	**1,083**	**1,083**	**1,083**	**1,083**	**1,083**	**1,083**

Notes:

1. Minimum flow requirements can be reduced no lower than the total project inflow.

Vernon Project

FERC Normal Operating Limits: 218.6 ft to 219.8 ft

Minimum Flow Requirements

	Required Flow on Given Start Date (cfs)					
	01-Jan	01-Apr	15-Apr	16-Jun	16-Jul	15-Oct
- Fish Ladder	-	-	260	260	-	-
- Downstream Fish Passage	-	390	390	390	390	340
- Aquatic Habitat Requirement	1,250	1,250	1,250	1,250	1,250	1,250
Minimum Project Flow[1] (i.e. greatest of above)	**1,250**	**1,250**	**1,250**	**1,250**	**1,250**	**1,250**

Northfield Mountain Project

FERC Normal Operating Limits: 938.0 ft to 1,000.5 ft

Turners Falls Project

FERC Normal Operating Limits: 176.0 ft to 185.0 ft

Minimum Flow Requirements

	Required Flow on Given Start Date (cfs)					
	01-Jan	**01-Apr**	**07-Apr**	**16-Jul**	**15-Sep**	**16-Nov**
Discharges to Bypass Reach						
- Spillway Ladder Attraction	-	300	300	-	-	-
- Sturgeon Requirement	-	-	-	120	120	-
- Aquatic Habitat Requirement	-	400	400	-	-	-
Minimum Bypass Flow[1] (i.e. greatest of above)	**-**	**400**	**400**	**120**	**120**	**-**
Discharges to Canal						
Gatehouse Ladder Attraction	-	270	270	-	270	-
Gatehouse Ladder	-	235	235	-	235	-
Minimum Requirement (i.e. cumulative)	**-**	**505**	**505**	**-**	**505**	**-**
Discharges from Canal						
Spillway Ladder	-	18	18	-	18	-
Cabot Ladder Attraction	-	335	335	-	335	-
Cabot Ladder	-	33	33	-	33	-
Log Sluice (downstream passage)	-	-	200	200	200	-
Minimum Requirement (i.e. cumulative)	**-**	**386**	**586**	**200**	**586**	**-**
Minimum Canal Flow[1] (i.e. greatest of to/from requirement)	**-**	**505**	**586**	**200**	**586**	**-**
Discharges from Project						
Minimum Project Flow[1]	**1,433**	**1,433**	**1,433**	**1,433**	**1,433**	**1,433**

Notes:

1. Minimum flow requirements can be reduced no lower than the total project inflow.

Holyoke Project

FERC Normal Operating Limits: 99.47 ft to 100.67 ft

Minimum Flow Requirements

	Required Flow on Given Start Date (cfs)		
	01-Jan	**01-Apr**	**01Dec**
Minimum Bypass Flow (i.e. greatest of above)	**-**	**150**	**-**