Relicensing Study 3.2.1

WATER QUALITY MONITORING STUDY

Study Report

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

Prepared for:

FirstLight™
GDF SUEZ

Prepared by:

GOMEZ AND SULLIVAN ENGINEERS

MARCH 2016

EXECUTIVE SUMMARY

FirstLight Hydro Generating Company (FirstLight) is the current licensee of the Northfield Mountain Pumped Storage Project (Northfield Mountain Project, FERC No. 2485) and the Turners Falls Hydroelectric Project (Turners Falls Project, FERC No. 1889). FirstLight has initiated with the Federal Energy Regulatory Commission (FERC, the Commission) the process of relicensing the Northfield Mountain and Turners Falls Projects using FERC's Integrated Licensing Process (ILP). The current licenses for the 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. 3.2.1 Water Quality Monitoring Study*.

The study plan and subsequent Field Sampling Plan developed and approved for this study contained four primary objectives: 1.) Characterize water temperature and dissolved oxygen (DO) within the Turners Falls Impoundment (TFI), bypass channel, power canal, and below Cabot Station, 2.) Determine potential impacts of the Turners Falls Project and Northfield Mountain Project on water temperature and DO, 3.) Compare collected data with applicable state water quality standards, and 4.) Describe water temperature and temperature rate of change in the Connecticut River between Cabot Station and the Holyoke Dam.

The study objectives were met by collecting data from 18 sites in the Connecticut River. The geographic scope of the study sites ranged from the inflow to the TFI below Vernon Dam, to locations in the Connecticut River downstream of the Turners Falls Project. Data were collected from April through mid-November, 2015. The 18 sites consisted of 16 continuous water quality monitoring locations and three vertical profile locations. At one of the sites, Site 7 above the Turners Falls Dam boat barrier line, both continuous and vertical profile data were collected. Nine of the continuous monitoring locations between Vernon Dam and below Cabot station (including 5 in the TFI, 2 in the bypass reach, 1 in the power canal and 1 downstream of Cabot Station before the Deerfield River confluence) were monitored for DO and temperature. The seven continuous monitoring locations below the Deerfield River confluence to Holyoke Dam were monitored for temperature only.

There were no significant deviations from the study plan. The timing of meter installation and specific monitoring locations varied slightly from the study plan for safety reasons and practical considerations.

Weather and flow conditions during the 2015 water quality sampling study period generally reflected typical conditions for the study area. April and May 2015 were drier in comparison to long-term averages. June was very wet and cool. The summer months of July, August and September experienced typical low flow, high temperature conditions. Flows during October-November were generally below average as well.

Vertical DO and temperature profiles collected at the three sites in the TFI showed no evidence of thermal stratification and a slightly negative DO gradient at times. The water column at all three profile locations was generally well-mixed throughout the sampling period.

Continuous DO and temperature data collected throughout the 2015 study period indicate that all state water quality standards were met. DO results from within the TFI, the bypass reach, the power canal, and below Cabot Station (i.e., Site 1 through Site 11) remained above the MA water quality standard of 5.0 mg/L minimum for Class B warm water fisheries. The minimum observed DO concentration was 5.8 mg/L (and 71.1% saturation) at Site 11 below Cabot Station.

The water temperatures observed at each location remained below the MA water quality standard of 28.3°C for Class B warm water fisheries. The maximum instantaneous temperatures observed across all sites ranged from 26.4 °C to 28.1°C. Monthly average water temperatures were very similar among all locations. August was the warmest month for all locations with an average water temperature of approximately 25°C.

DO and water temperature trends in the TFI generally follow a diurnal pattern in response to solar warming and photosynthesis whereby DO concentrations and water temperatures are highest during daylight hours

and lowest overnight. During periods of generation at the Northfield Mountain Project, subtle, short-term differences in water temperatures and DO at the monitoring site in the Northfield Mountain tailrace were observed compared to other sites in the TFI.

Water temperature and DO levels in the bypass reach were very similar to one another under minimum flow conditions, showing a typical diurnal pattern. Highest concentrations of DO were most commonly observed in the bypass reach downstream of Turners Falls Dam where DO supersaturation (over 100%) was observed at times; the highest percent saturation values were recorded at Site 8, upstream of Station No. 1, during June. Further downstream, DO levels dissipated at Site 9 near Rawson Island. DO was generally found to increase in the bypass reach in relation to spillage from Turners Falls Dam; however, other hydraulic and biological processes are likely occurring in the bypass reach during this period leading to high diurnal DO levels.

Water temperature and DO levels in the power canal track similar to conditions at Site 7 in the TFI. Similarly, water quality conditions just downstream of Cabot Station (Site 11) track closely to conditions in the power canal while Cabot Station is generating. When Cabot Station is off-line, downstream conditions are dictated by flow and water quality conditions in the bypass reach.

In the Connecticut River downstream of Cabot Station, water temperature patterns were similar from site to site (Site 11-18). Monthly average water temperatures from Sites 11-18 were within ±1.0°C and typical diurnal patterns were apparent. Some of the sites below Cabot Station were relatively shallow during the summer months, and therefore, the range of diurnal water temperatures was greater compared to deeper sites. Water temperature daily ranges and hourly rates of change are higher at downstream locations compared to those at Site 11, just downstream of Cabot Station. The maximum rates of change for temperature were between 1.3 and 1.5°C/hr. Average rates of change are typically 0.1 to 0.2°C/hr at sites below Cabot Station. Water temperature hourly rate of change values are similar regardless of Cabot Station operations during periods of low flow.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

BP	barometric pressure
Commission	Federal Energy Regulatory Commission
CRWC	Connecticut River Watershed Council
cfs	cubic feet per second
DO	dissolved oxygen
FERC	Federal Energy Regulatory Commission
FirstLight	FirstLight Hydro Generating Company
FSP	Field Sampling Plan
ft	feet
hr	hour
ILP	Integrated Licensing Process
ISR	Initial Study Report
kW	kilowatt
kWH	kilowatt/hour
MADEP	Massachusetts Department of Environmental Protection
MA NHESP	Massachusetts Natural Heritage and Endangered Species Program
MADFW	Massachusetts Department of Fish and Wildlife
mg/L	milligrams per liter
mi^2	square miles
msl	mean sea level
MW	megawatt
MWH	megawatt/hour
NOAA	National Oceanic and Atmospheric Administration
Northfield Mountain Project	Northfield Mountain Pumped Storage Project
PAD	Pre-Application Document
%sat	percent saturation
PSP	Proposed Study Plan
QA/QC	Quality Assurance/Quality Control
RoC	rate of change
RSP	Revised Study Plan
SD1	Scoping Document 1
SD2	Scoping Document 2
SPDL	Study Plan Determination Letter
Turners Falls Project	Turners Falls Hydroelectric Project
TFI	Turners Falls Impoundment
USGS	United States Geological Society
VY	Vermont Yankee Nuclear Power Plant
WQ	water quality

1 INTRODUCTION

FirstLight Hydro Generating Company (FirstLight) is the current licensee of the Northfield Mountain Pumped Storage Project (Northfield Mountain Project, FERC No. 2485) and the Turners Falls Hydroelectric Project (Turners Falls Project, FERC No 1889). FirstLight has initiated with the Federal Energy Regulatory Commission (FERC, the Commission) the process of relicensing the Northfield Mountain and Turners Falls Projects using 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, and are 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, would 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. 3.2.1: Water Quality Monitoring Study*. For this study, the primary modification FERC requested to the RSP was for FirstLight to develop a study plan component to include temperature monitoring along the Connecticut River between Cabot Station and the Holyoke Dam. The results of the temperature monitoring would be used to describe temperature and temperature rate of change associated with peaking operations. The additional temperature monitoring locations were selected in consultation with interested stakeholders.

1.1 Field Sampling Plan

FirstLight developed a Field Sampling Plan (FSP) in consultation with stakeholders which detailed the water quality monitoring sites and sampling protocols, including additional water temperature monitoring sites below Cabot Station. FirstLight submitted a Draft Water Quality Monitoring Study Field Sampling Plan to stakeholders on June 30, 2014 and requested written comments be provided by July 28, 2014. Comments were received from the following entities:

- Massachusetts Department of Environmental Protection (MADEP)

- Connecticut River Watershed Council (CRWC)
- Massachusetts Natural Heritage and Endangered Species Program (NHESP)

The Field Sampling Plan was revised to address stakeholder comments and filed with the Initial Study Report (ISR) on September 15, 2014. The Field Sampling Plan (Appendix A) was approved without modification in FERC's January 22, 2015 Determination on Requests for Study Modifications and New Studies.

1.2 Study Goals and Objectives

The study objectives include:

- Characterize water temperature and dissolved oxygen (DO) within the Turners Falls Impoundment (TFI), bypass channel, power canal, and below Cabot Station.
- Determine potential impacts of the Turners Falls Project and Northfield Mountain Project on water temperature and DO.
- Compare collected data with applicable state water quality standards.
- Describe water temperature and temperature rate of change in the Connecticut River between Cabot Station and the Holyoke Dam.

1.3 Water Quality Standards and River Classification

The TFI is approximately 20 miles long, with approximately 5.7 miles located in NH and the remainder in MA. Although the Turners Falls Project and Northfield Mountain Project boundaries span three states, the Projects' intake/tailrace are located in Massachusetts. The Massachusetts surface water quality standards, 314 CMR 4.00 (MADEP, 2013), assign all inland, coastal and marine waters to classes according to the intended beneficial uses of those waters. The Commonwealth of Massachusetts classifies the entire Connecticut River as a Class B, warm water fishery.

Class B waters shall be suitable for a) supporting aquatic life, b) recreational uses such as swimming and boating, and c) fish consumption. MA Class B water quality standards specify a minimum dissolved oxygen concentration of 5 mg/L, water temperatures shall not exceed 83°F and the rise in temperature due to discharge shall not exceed 5°F based on the minimum expected flow for the month.

New Hampshire surface water quality standards (RSA 485-A:8) apply to the Connecticut River upstream of the Massachusetts border, where the river borders New Hampshire and Vermont. The state of New Hampshire has designated the entire Connecticut River as a Class B warm water fishery. NH Class B water quality standards require that waters have no less than 75% DO saturation based on a daily average and no less than a minimum DO concentration of 5 mg/L. Any associated increases in temperature "*shall not be such as to appreciably interfere with the uses assigned to this class*" (section 485-A:8).

Vermont has designated most of the Connecticut River as a Class B warm water fishery waterbody. The VT water quality standards for Class B water bodies (10 V.S.A. § 1250) require that 1) the DO be no less than 5 mg/l and 60% saturation at all times, and 2) allowable increases in temperature are dependent on ambient temperature.

The water quality standards for MA, NH and VT are listed in Table 1.3-1.

1.4 Study Area

1.4.1 Turners Falls Project Layout

The Turners Falls Dam creates the Turners Falls Impoundment (TFI), which is approximately 20 miles long, and extends upstream to the base of the Vernon Hydroelectric Project (FERC No. 1904) (see Figure 2.1-1). Inflow to the TFI is controlled predominantly by the Vernon Hydroelectric Project discharge and by the Ashuelot and Millers Rivers. The Ashuelot and the Millers Rivers are both equipped with United States Geological Survey (USGS) streamflow gages. Per the current FERC license, the elevation of the TFI varies between a minimum of 176.0 ft mean sea level (msl) to a maximum of 185.0 ft (msl); a 9-ft fluctuation as measured at the Turners Falls Dam.

The Turners Falls Dam is located on a "Z turn" in the river, and is oriented on a northeast-southwest axis, with the impounded area on the east side of the dam, and extending north. At the southwest end of the Turners Falls Dam is the gatehouse. Below the dam, originating at the gatehouse, is the Turners Falls power canal. The gatehouse controls the magnitude of flow passing into the power canal. The power canal is approximately 2.1 miles long. Associated with this power canal are two hydroelectric generating facilities[1]: Station No. 1 and Cabot Station. Station No. 1 is located approximately one-third of the way down the power canal. Water is conveyed from the power canal, to a small branch canal that feeds the Station No. 1 turbines, before discharging into the bypassed reach of the Connecticut River. Station No. 1 has a hydraulic capacity of 2,210 cfs. Cabot Station is located at the downstream terminus of the power canal, and it discharges into the main stem Connecticut River. Cabot Station has a hydraulic capacity of 13,728 cfs. Station No. 1 and Cabot Station discharge into the Connecticut River approximately 0.9 miles and 2.7 miles downstream of the Turners Falls Dam, respectively.

The bypass reach, which runs from the base of Turners Falls Dam to the Cabot Station tailrace, is approximately 2.7 miles long. Per the current FERC license, minimum flows[2] are provided to the bypass reach beginning May 1 annually and continuing until water temperatures fall below 7°C (typically November) to enhance conditions for upstream migratory species and Shortnose Sturgeon.

1.4.2 Northfield Mountain Project Layout

The Northfield Mountain Project is a pumped-storage facility that uses the TFI as its lower reservoir. The tailrace of the Northfield Mountain Project is located approximately 5.2 miles upstream of Turners Falls Dam, on the east side of the TFI. This Project's upper reservoir is a man-made structure situated atop Northfield Mountain, to the east of the tailrace. During pumping operations, water is pumped from the TFI to the upper reservoir. When generating, water is passed from the upper reservoir intake via an underground pressure shaft to an underground powerhouse. An underground tailrace tunnel then delivers water back to the TFI. The maximum pumping and generating capacity of the Northfield Mountain Project is 15,200 cfs and 20,000 cfs, respectively.

[1] Other water users include PaperLogic (113 cfs capacity), Turners Falls Hydro, LLC (288 cfs capacity), and the United States Geological Survey Conte Anadromous Fish Laboratory (withdraws can range from 2 to 200 cfs pending time of year).

[2] Under the current FERC license for the Turners Falls Project, FirstLight is required to release a continuous minimum flow of 1,433 cfs or inflow, whichever is less, below the Project. In addition, the license also stipulates a continuous minimum flow of 200 cfs is maintained in the bypass reach starting on May 1, and increases to 400 cfs when fish passage starts by releasing flow through a bascule gate. The 400 cfs continuous minimum flow is provided through July 15, unless upstream fish passage season has concluded early, in which case the 400 cfs flow is reduced to 120 cfs to protect Shortnose Sturgeon. The 120 cfs continuous minimum flow is maintained in the bypass reach from the date the fishways are closed (or by July 16) until the river temperature drops below 7 °C, which typically occurs around November 15.

Table 1.3-1 State Water Quality Standards for Class B Waters – Warm Water Fisheries

State	DO Standard	Temperature Standard
MA	No less than 5.0 mg/L. "Natural variations to be maintained. Where natural background conditions are lower, DO shall not be less than natural background conditions."	Shall not exceed 83°F (28.3°C). Rise in temperature due to discharge shall not exceed 5°F (2.8°C) based on minimum expected flow for the month.
NH	75% DO saturation based on daily average, and an instantaneous minimum dissolved oxygen concentration of at least 5 mg/L	Related temperature increases shall not interfere appreciably with the uses of this class.
VT	No less than 5 mg/L and 60% DO saturation at all times.	Shall ensure full support of aquatic flora, fauna and habitat uses.

2 MATERIALS AND METHODS

2.1 Overview of Monitoring Locations

Per the FERC-approved RSP, there were 11 sampling sites from the upper end of the Turners Falls Impoundment to below Cabot Station. In addition, seven (7) temperature monitoring locations were sited between Cabot Station and the Holyoke Dam for a total of 18 sampling locations. Figure 2.1-1 shows the water quality monitoring locations. Photographs of each location are shown in Appendix B. Smaller scale maps of each site showing available bathymetry data are contained in Appendix C.

Vertical DO and temperature profiles were collected at three (3) of the deepest locations within the TFI. Continuous temperature data were collected at seven (7) locations between Cabot Station and the Holyoke Dam. Each sampling location and monitoring periods are further described in Table 2.1-1.

2.2 Water Quality Equipment Specifications

In situ spot measurements were performed using a YSI Pro ODO Handheld DO/temperature meter and a hand-held thermometer traceable to a NIST-certified thermometer was used to periodically check sensor accuracy. Continuous monitoring of temperature and DO were conducted using HOBO Dissolved Oxygen Loggers (Model U26-001), HOBO Water Temp Pro v2 loggers (Model U22-001) and HOBO Water Level Loggers (U20-001-01). Note that the water level loggers were also used to collect temperature data. The accuracy, range, and resolution of each sensor are outlined in Table 2.2-1.

2.3 Vertical DO and Temperature Profiles

The DO/temperature profile sampling in the TFI started on April 3, 2015 at Sites 2 and 6. There was ice cover at the Site 7 location in early April 2015 preventing access, followed by flows in excess of 20,000 cfs during subsequent sampling events. The boat barrier upstream of the Turners Falls Dam was eventually installed on May 13, 2015 and the first vertical profile at Site 7 was collected on May 14, 2015. FirstLight's safety protocol dictated that study boats were not permitted downstream in the Barton Cove area if flows exceeded approximately 20,000 cfs and the boat barrier had not been installed (FirstLight, 2015).

The vertical profiles were collected in the early morning, generally between 6:00-9:00 am. As requested by MADEP, vertical profile data through June 30 were provided to MADEP on July 13, 2015 to determine if early morning vertical profile collection was justified. MADEP approved the proposed schedule of starting at 6:30-7:00 am and finishing around 9:00 am for biweekly profiles (personal communication from R. Kubit, MADEP, July 20, 2015).

The temperature and DO profiles were collected using a portable YSI Pro ODO meter equipped with a 50 meter cable. The DO sensor was calibrated prior to use following the water saturated air calibration method. Calibration results were recorded on the applicable field data sheets or notebook.

The YSI Pro ODO meter was used to collect temperature and DO (% saturation and mg/L) readings at 1 meter increments, from the surface of the water to between 1 and 0.5 meters of the river bottom. Data were collected to characterize the profile of temperature and DO, and the timing of any stratification that might occur within the TFI.

The last vertical profile data were collected on November 11, 2015 at Site 7 (due to boat barrier being removed later that day) and on November 18, 2015 at Sites 2 and 6.

2.4 Continuous Water Quality Data Monitoring

A total of sixteen (16) data loggers were deployed to continuously monitor DO and/or temperature in the Connecticut River. These data were collected to characterize water temperature and DO conditions within

the TFI, bypass channel, power canal, and the Connecticut River below Cabot Station, and to determine potential impacts of the Turners Falls Project and Northfield Mountain Project on water temperature and DO. Table 2.1-1 summarizes the deployment and retrieval period for each of the 16 continuous data loggers.

Deployment procedures for the continuous temperature and DO data loggers generally followed procedures employed by the MADEP, Division of Watershed Management Standard Operating Procedure of Multiprobe Deployment (MADEP, 2007), as detailed in the approved FSP (Appendix A). GPS coordinates and photo documentation were obtained for each location; weather, river flow, and condition of the logger were recorded in a field notebook during deployment, bi-weekly sampling, and retrieval.

2.4.1 Dissolved Oxygen Loggers

Nine data loggers were deployed to record DO and temperature data at fifteen minute intervals. At the continuous monitoring sites in the TFI, the loggers were deployed to a point approximating 25% of the river depth. Water depths in these locations ranged from 20-50 feet at the time of deployment as described in Table 2.1-1.

The logger at Site 10 in the power canal was deployed to mid-depth (approximately 10 feet). Sites 8-9 in the bypass reach were relatively shallow, so the continuous loggers were secured to a weight on the bottom. The sensors were oriented approximately 0.5 feet off the bottom. Site 11 below Cabot Station was relatively deep, and the logger there was deployed from an anchored buoy mid-channel to a point approximating 25% of the river depth.

One HOBO (Model U20-001-04) was placed in the secure fenced-in portion of the power canal to collect barometric pressure (BP) data. The BP data was essential to convert DO mg/L data into DO percent saturation data.

The loggers were serviced approximately every two weeks. Servicing included collecting independent spot measurements (using a YSI Pro ODO meter), downloading the continuous data, and cleaning and calibrating the loggers, as necessary. Offloaded data were reviewed between site visits to assure the loggers were performing properly and within acceptable ranges of error for each parameter.

2.4.2 Temperature Loggers

The continuous temperature loggers below Cabot Station were installed on April 10, 2015, once the boat launch was in open water and clear of ice. Two types of data loggers were used to collect continuous temperature data (i.e., HOBO Temp Data Logger Model U22-001 and HOBO Water Level Logger Model U20-001). The loggers were set to continuously monitor temperature at fifteen minute intervals.

The loggers were serviced approximately every two weeks. Servicing included collecting independent spot measurements (using a YSI Pro ODO meter) and downloading the continuous data. Offloaded data were reviewed between visits to assure the loggers were performing properly, and within acceptable range of error.

2.5 Field QA/QC Procedures

Adherence to standard methods and QA/QC procedures for all water quality monitoring helps ensure that the resulting data will be accurate, precise, comparable, and representative. This section describes the QA/QC procedures that were conducted throughout the study period. Only personnel trained or those experienced in the measurement and data recording techniques described above conducted the field data collection. The water quality instrumentation utilized in this study was maintained and calibrated following the manufacturer's instructions. In addition, applicable QA/QC methods, as detailed in the Field Sampling Plan, were followed.

2.5.1 Vertical Profile Monitoring

All vertical profile measurements were conducted using the YSI Pro ODO meter. To reduce the likelihood of measurement error, the YSI Pro ODO meter was calibrated according to the manufacturer's recommendations prior to sampling, on the day of field work. The instrument calibration results were recorded on a field data sheet and stored electronically upon returning from the field. Field data were collected only after the calibration checked out. Additional details on calibration procedures are contained in the FSP (Appendix A). A hand-held thermometer traceable to a NIST-certified thermometer was used to check YSI sensor accuracy prior to collecting profile data each day of sampling.

Profile measurements were recorded after the meter displayed a stable reading for 30 seconds at each 1-meter depth increment. One replicate measurement was collected at a random depth interval at least once per vertical profile, or after every 20th measurement. Two replicate measurements were collected for profiles greater than 20 meters. Replicate data were verified to be within instrument accuracy specifications for temperature and DO compared to the initial measurements made for the same depth. The maximum difference between each profile replicate measurement was 0.1 mg/L or 0.1°C. The YSI Pro ODO meter and NIST traceable thermometer temperatures were always within ±0.5°C.

2.5.2 Continuous Monitoring

All continuous measurements were conducted using HOBO Dissolved Oxygen Loggers, HOBO Water Temp Pro v2 loggers or HOBO Water Level Loggers. Temperature sensors were factory calibrated, and each DO logger was calibrated according to manufacturer's specifications prior to deployment. All loggers were tested in a common bath prior to deployment to ensure they were in agreement (MADEP, 2009).

Duplicate DO and/or temperature measurements ("spot checks") were collected at each site with a YSI Pro ODO meter during the deployment, retrieval, and bi-weekly servicing of each logger. A spot check was performed using the YSI Pro ODO at logger depth. Data were recorded in a field logbook and compared against retrieved logger data (collected within the same 15 minute time interval) to ensure the logger was functioning properly. Data were retrieved and analyzed for consistency by an experienced biologist after each field visit. Any erroneous data were rejected from the analysis. If the continuous DO value did not match the concurrent spot check measurement by ±0.4 mg/L, the continuous logger was re-calibrated in the field and the continuous data set for that biweekly period was adjusted in the office during the data review period.

Vertical profile data were similar throughout the water column, and comparable to concurrent continuous water quality meter data collected at locations within the TFI. This similarity confirmed that continuous loggers collected data within the TFI at a depth representative of the entire water column.

At the downstream water temperatures sites, spot measurements were collected from a mid-channel, mid-depth location and compared to logger locations (tethered to shore). Results indicated that water temperatures varied ≤0.6°C across the channel compared to logger locations.

2.6 Data Compilation and Review

2.6.1 Weather, Flow and Operations Data

To support the analysis of the water quality data, weather flow and operations data were obtained for the period concurrent with the water quality monitoring period. Historical weather data were obtained online from the National Oceanic Atmospheric Administration (NOAA) Online Weather (NOWdata) query system. Although the historical periods of record for each location are different, due to the completeness of each data set, the Sunderland weather station data (1979 - 2015) were used for precipitation and the Greenfield No. 3 weather station data (2000 - 2015) were used for air temperature. Visual observations of weather conditions were also recorded at the Project on each sampling day.

Real-time and historical flow data were obtained from the Connecticut River USGS Gage at Montague City, MA (Gage No. 01170500).

Operations data for 2015 in 15-minute increments were provided by FirstLight for the following locations.

- Vernon Hydroelectric Project discharge - this includes both the powerhouse discharge and Vernon Dam spill. Spill is computed using rating curves. The maximum hydraulic capacity of the Vernon Hydroelectric Project is 17,130 cfs.
- Northfield Mountain Project Generation and Pumping flows - FirstLight measures the pump and generation discharge via Accusonic equipment. Based on the equipment standards, it measures flows to within 3% of the actual flow.
- Turners Falls Dam Spill - FirstLight uses rating curves to compute the estimated spill at the dam.
- Gatehouse Discharge - FirstLight uses rating curves to compute the estimate flow through the gatehouse into the power canal.
- Station No. 1 - FirstLight records total station generation in MWH that can be converted to flow. The maximum hydraulic capacity of Station No. 1 is 2,210 cfs. The generation was converted to flow with the equation 1 kW = 0.3706 cfs.
- Cabot Station - FirstLight records total station generation in MWH that can be converted to flow. The maximum hydraulic capacity of Cabot Station is 13,728 cfs. The generation was converted to flow with the equation 1 kWH = 0.2214 cfs.

2.6.2 Water Quality Data Compilation and Review

All temperature and DO measurements collected at the three vertical profile locations were recorded on field data sheets the day of sampling. Collected data included DO and water temperature measurements, general weather and flow conditions, and QA/QC data records (e.g., spot checks, calibration notes, replicate measurements). Continuous temperature and continuous DO data collected using the HOBO data loggers were stored in the loggers' memory and downloaded during each bi-weekly sampling event.

All field collected data underwent a thorough QA/QC review process to ensure accuracy and completeness of the dataset. Data were reviewed at the end of each day (vertical profiles) or after each bi-weekly service throughout the course of the study (continuous data). Continuous water quality data were analyzed for outliers, erroneous data points and instrument drift.

Any continuous DO data that did not match the concurrent spot measurements to within $\pm$0.4 mg/L were adjusted using the HOBOware DO Data Assistant. The HOBOware DO Assistant uses the spot check measurements collected at the beginning and end of the biweekly period to adjust the DO values within that period. This correction process was only performed if biofouling on the logger was believed to compromise the measurements, or if the readings from the loggers were not within ±0.4 mg/L of the spot check. Of the 130,566 continuous DO data points, 21% were adjusted to reflect concurrent spot check measurements.

Once the data set was reviewed and complete, the continuous DO and temperature data were paired with contemporaneous FirstLight operations and USGS gage flow data to investigate possible relationships between DO, temperature, river flow, and Project operations.

2.7 Protocol Deviations

2.7.1 Sampling Period

The FERC-approved RSP called for commencement of continuous water temperature sampling and collection of vertical profiles beginning on April 1, 2015. The study area was initially visited on March 31, 2015 at which time the monitoring equipment was installed in the bypass reach and canal (Sites 8-10).

Flows in the bypass reach were low on this date. Some of the continuous loggers were not in place by April 1 due to ice cover on the Connecticut River causing site inaccessibility (see Photo Numbers 1 and 2 of the boat launches taken on March 31, 2015 in Appendix B).

With the exception of Site 7 at the boat barrier line, the continuous temperature loggers in the TFI were installed on April 3, 2015 and vertical profile measurements were initiated. There was ice cover on Barton Cove into April and because the boat barrier was not installed until May 13, 2015, safety concerns prevented installation of a temperature logger and collection of a vertical profile at Site 7 until May 14, 2015.

The continuous temperature loggers below Cabot Station were installed on April 10, 2015, once the Sunderland boat launch was open and clear of ice.

Every effort was made to service each continuous data logger and perform vertical profiles on a biweekly schedule, but there were instances where loggers/profile sites could not be reached on a biweekly cycle due to high flows or other reasons. The study plan specified that DO monitoring would occur from June 1 through September 30, 2015. Most DO meters were in place by mid-May and remained into October, depending on the location. Table 2.1-1 lists the deployment and retrieval period for each sampling location.

2.7.2 Sampling Locations

There were a few minor deviations from the sampling locations specified in the study plan as described below.

At Site 8 and Site 9 in the bypass reach, the DO loggers were initially deployed just downstream of their intended locations due to high flows in the bypass reach required for another relicensing study (Study No. 3.3.2 *Evaluate Upstream and Downstream Passage of Adult American Shad*). Site 8 was initially installed on the left bank just upstream of Station No. 1, and Site 9 was initially installed just downstream of Rawson Island. The loggers were moved to their intended locations once the sites became accessible (July 10 for Site 8 and July 23 for Site 9).

The study plan envisioned that the monitoring site in the power canal (Site 10) would be located on the 11th Street Bridge. The actual deployment location was at the old railroad bridge across the canal located about 950 feet upstream of the 11th Street Bridge. This area was chosen because it was a more secure area than the public bridge.

At Site 12, the temperature logger was initially installed too far upstream on April 10. This logger was repositioned to the intended location at the railroad bridge on April 30, 2015. Temperature data from Site 12 for the period April 10 - 30 were not used in this analysis.

2.7.3 Missing or Rejected Data

Issues encountered with the continuous data loggers are summarized as follows:

- Site 1: There are no data available from September 3 through September 18 due to an equipment malfunction.
- Site 8: This logger was dewatered for a short period of time on July 10 due to a change in operations associated with special releases provided for other relicensing studies.
- Logging errors occurred periodically at Site 8 and 9. Certain data records within the continuous data series would be reported as "Sensor Data Error." All data points associated with logging errors were deleted from the data set and not included in the results.
- Site 10: The annual power canal drawdown occurred from October 5 to October 11; therefore, no DO and temperature data were obtained during this period.

- Site 14: Continuous data were rejected from June 2-10 because the logger broke loose due to a high flow event.
- Intermittent periods of continuous temperature data were also rejected from downstream locations (Sites 12-18) during periods of low flow when the logger became exposed to the air. Periods included:
    - Sites 12 and 13 – portions of May 28 due to low flows.
    - Site 13 - intermittent periods between August 9-17 due to vandalism/low flows (i.e., logger tampered with and moved to a shallower location).
    - Site 13 - intermittent periods between August 23-September 2; large woody debris snagged on tether cable causing logger movement to shallower location.
    - Site 14 at Second Island – intermittent periods between May 18-28 due to low flows.

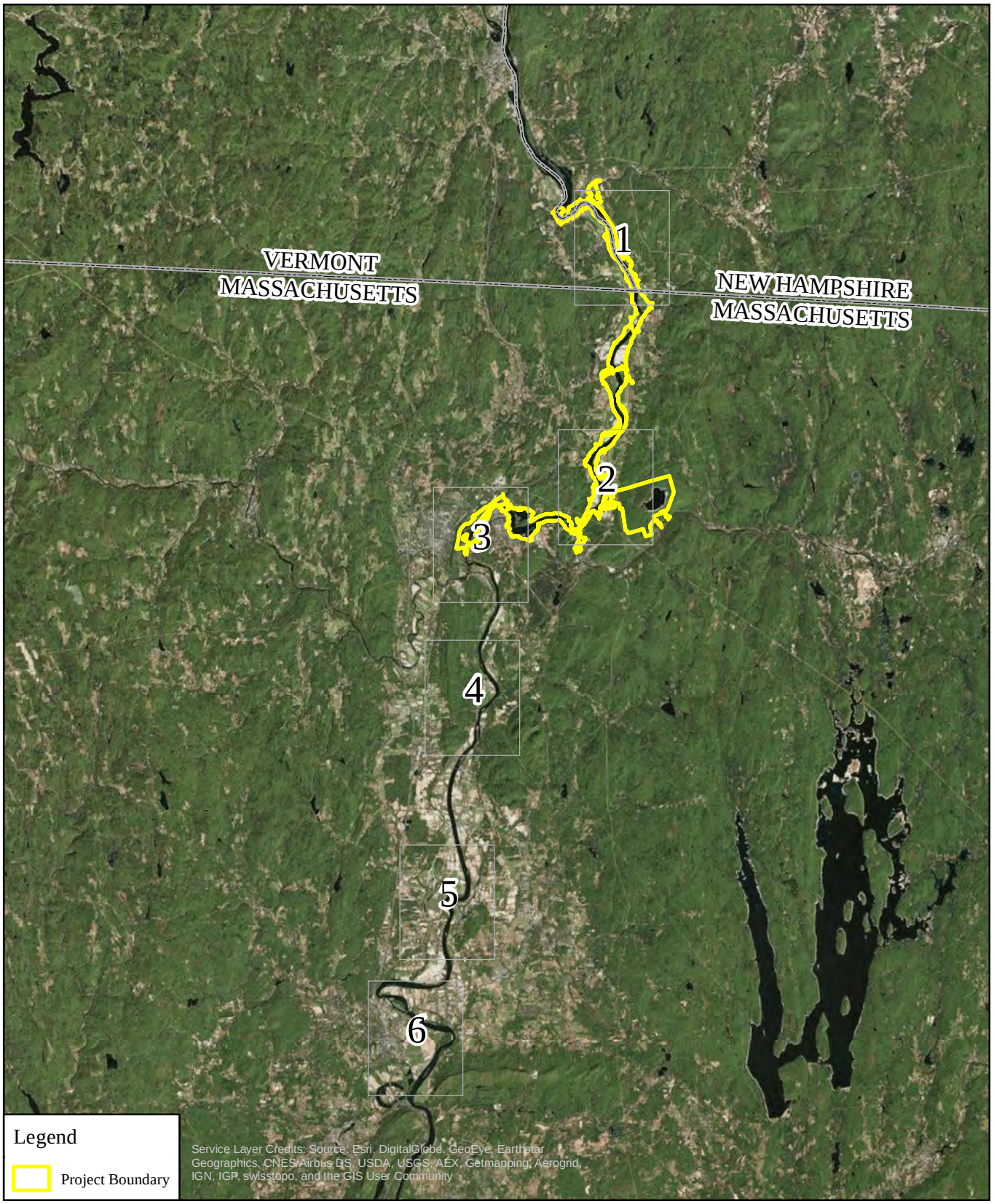
Table 2.1-1: Water Quality Monitoring Site Descriptions and Period

Site No.	Monitoring Type	Location	Logger Monitoring Dates		Vertical Profile Time Period
			Temperature	DO	
Connecticut River- Turners Falls Impoundment					
1	Continuous	Below the Vernon Dam and Ashuelot River Confluence	4/3/15-11/18/15	5/14/15-10/9/15	--
2	Profile	Deep area upstream of Northfield Mountain	--	--	4/3/15-11/18/15
3	Continuous	Above the Northfield Mountain Tailrace	4/3/15-11/18/15	5/14/15-10/9/15	--
4	Continuous	Northfield Mountain Tailrace	4/3/15-11/18/15	5/14/15-10/9/15	--
5	Continuous	Below the Northfield Mountain Tailrace	4/3/15-11/18/15	5/14/15-10/9/15	--
6	Profile	Deepest area of Turners Falls Impoundment	--	--	4/3/15-11/18/15
7	Profile and Continuous	Upstream of the Turners Falls Dam at Boat Barrier	5/14/15-11/11/15	5/14/15-10/9/15	5/14/15-11/11/15
Connecticut River- Bypass Reach					
8	Continuous	Upstream of Station No. 1	3/31/15-11/17/15	5/14/15-10/22/15	--
9	Continuous	Upstream of Rock Dam; west channel at Rawson Island.	3/31/15-11/17/15	5/13/15-10/22/15	--
Turners Falls Power Canal					
10	Continuous	At the Railroad Bridge	3/31/15-11/17/15	5/14/15-11/17/15	--
Connecticut River- Cabot Station to Holyoke Dam					
11	Continuous	Below Cabot Station tailrace, upstream of Deerfield River	4/10/15-11/18/15	5/13/15-10/8/15	--
12	Continuous	Downstream of the Deerfield River confluence at railroad bridge	4/30/15-11/18/15	--	--
13	Continuous	Third Island	4/10/15-11/18/15	--	--
14	Continuous	Second Island, near shore of island.	4/10/15-11/18/15	--	--
15	Continuous	Submerged shallow bar	4/10/15-11/18/15	--	--
16	Continuous	Submerged shallow bar	4/10/15-11/18/15	--	--
17	Continuous	River right channel at Elwell Island	4/10/15-11/18/15	--	--
18	Continuous	Mitch’s Island	4/10/15-11/18/15	--	--

Table 2.2-1: Water Quality Instrument Specifications

Parameter	Specification	Description
HOBO® Dissolved Oxygen Logger (U26-001)		
Optical Dissolved Oxygen (mg/L)	Operating Range	0 to 30 mg/L
	Accuracy	0.2 mg/L up to 8 mg/L; 0.5 mg/L from 8 to 20 mg/L
	Resolution	0.02 mg/L
Temperature (°C)	Operating Range	-5 to 40°C
	Accuracy	0.2°C
	Resolution	0.02°C
YSI Pro ODO Meter (50 meter cable graduated in 1-meter increments)		
Optical Dissolved Oxygen (mg/L)	Range	0 to 50 mg/L
	Accuracy	± 0.1 mg/L (0 to 20 mg/L) or 1% of reading
	Resolution	0.01 mg/L
Dissolved Oxygen (% saturation)	Range	0 to 500% air saturation
	Accuracy	±1% of reading (0 to 200% air saturation)
	Resolution	0.1% air saturation
Temperature (°C)	Range	-5 to 70°C
	Accuracy	±0.2°C
	Resolution	0.1°C
Barometer (mmHg)	Range	375 to 825 mmHg
	Accuracy	±1.5 mmHg (0 to 50°C)
	Resolution	0.1 mmHg
Control Company Traceable® Waterproof/ Shockproof Thermometer		
Temperature (°C)	Range	–50 to 300°C
	Resolution	0.1°C from –20 to 200°C
	Accuracy	±0.4°C between 0 and 100°C at tested points
HOBO® Water Temp Pro v2 (U22-001)		
Temperature (°C)	Range	-40 to 70°C in air; 50°C maximum in water
	Accuracy	±0.21°C (o to 50°C)
	Resolution	0.02°C at 25°C
HOBO® Water Level Logger (U20-001-01)		
Temperature (°C)	Range	-20° to 50°C
	Accuracy	0.37°C at 20°C
	Resolution	0.1°C at 20°C
Pressure/Depth	Operating Range	0 to 30 psia; approx. 0 to 9 m of water depth at sea level
	Accuracy	Water depth typical error*: 0.5 cm Maximum error: 1.0 cm water
	Resolution	0.003 psi, 0.21 cm water

** With accurate reference water level measurement and Barometric Compensation Assistant data.*



FirstLight™
GDF SUEZ

Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)
Relicensing Study 3.2.1

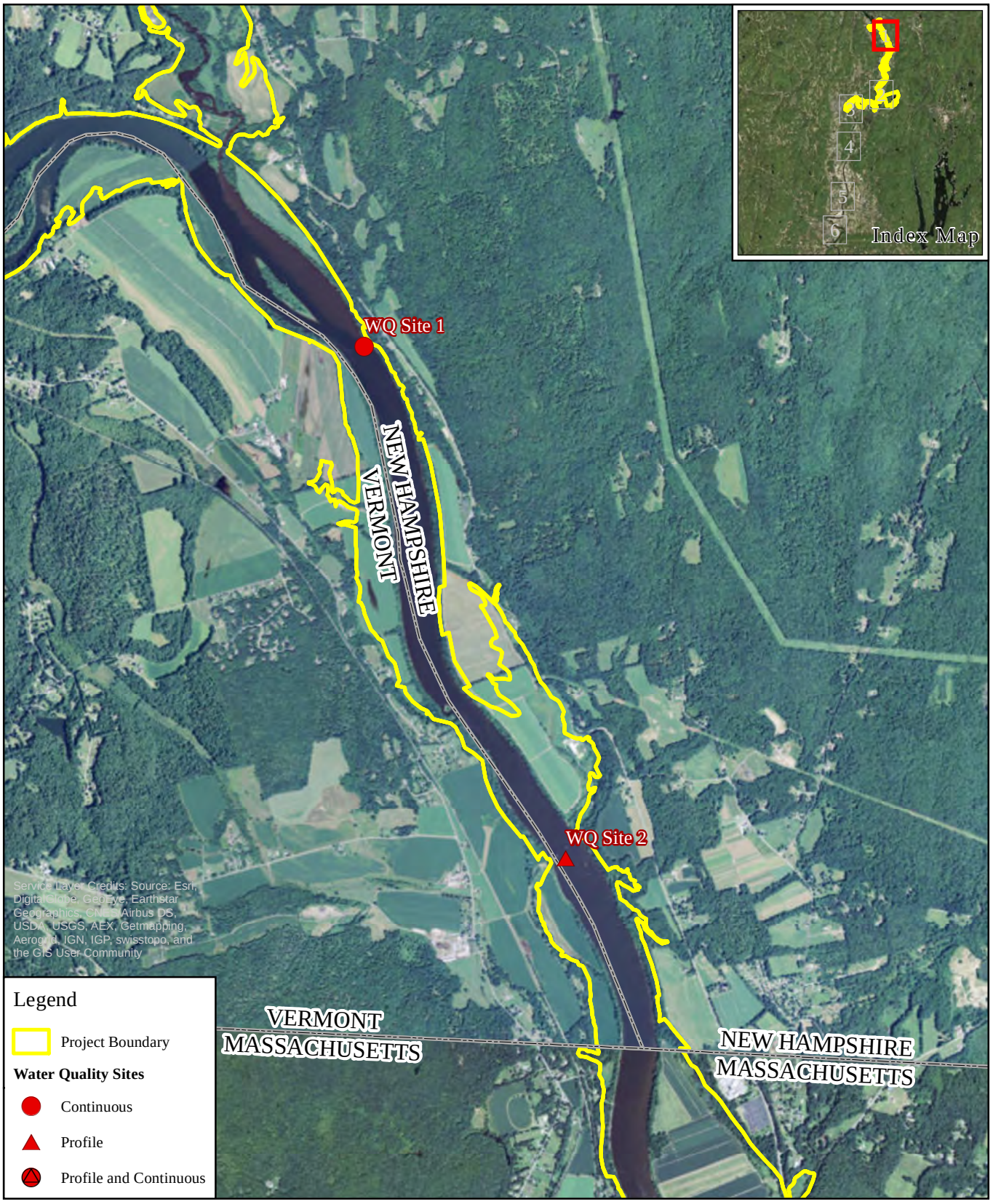
N

0 2.5 5 10 Miles

Figure 2.1-1:
Water Quality Sampling Locations

Map Index

Path: W:\gis\studies\3_2_1\maps\Figure_4_1_1.mxd



Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)
Relicensing Study 3.2.1

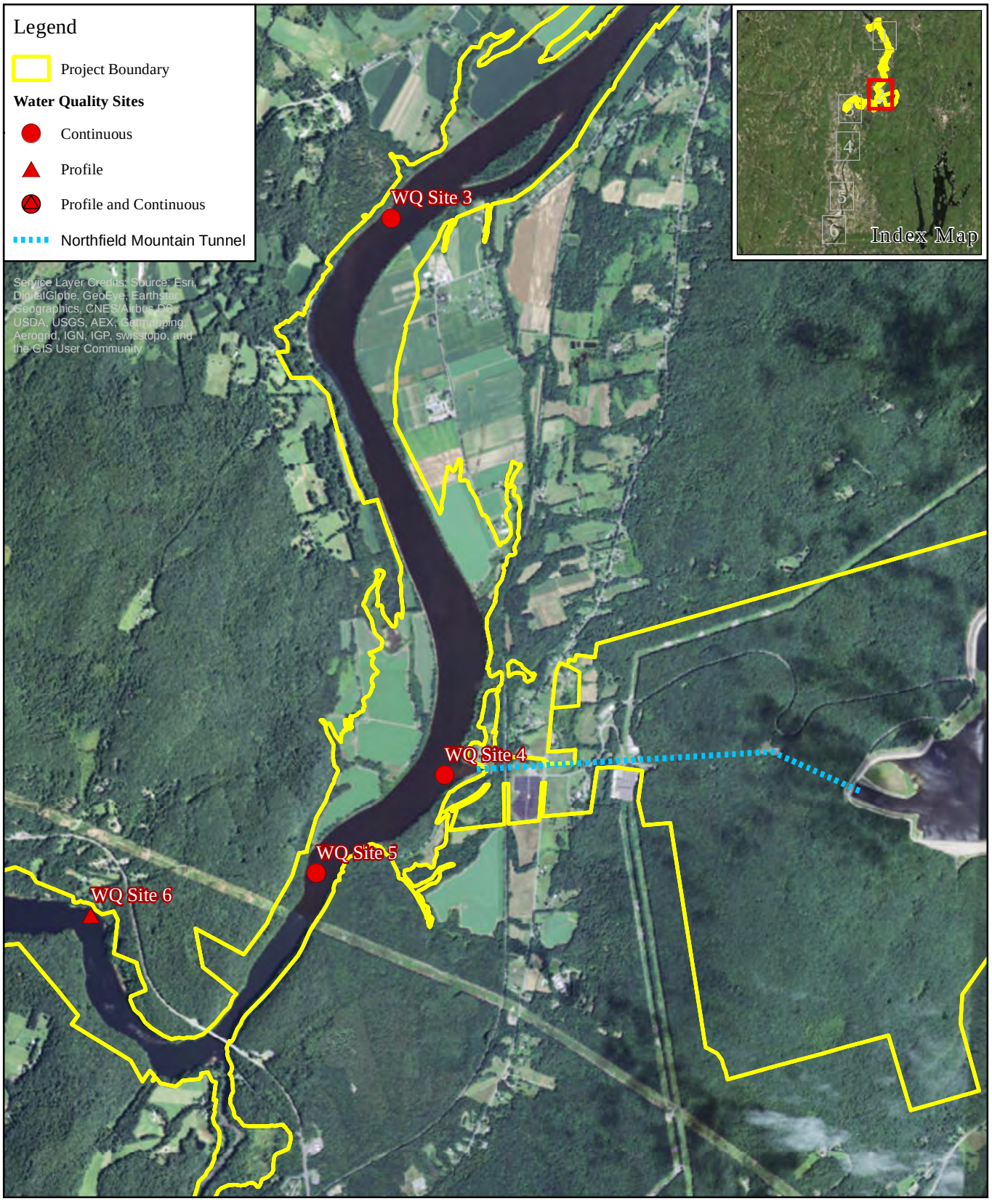
Figure 2.1-1:
Water Quality Sampling Locations

Map 1

N

0 0.25 0.5 1 Miles

Path: W:\gis\studies\3_2_1\maps\Figure_2_1_1.mxd



FirstLight™
GDF SUEZ

Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)
Relicensing Study 3.2.1

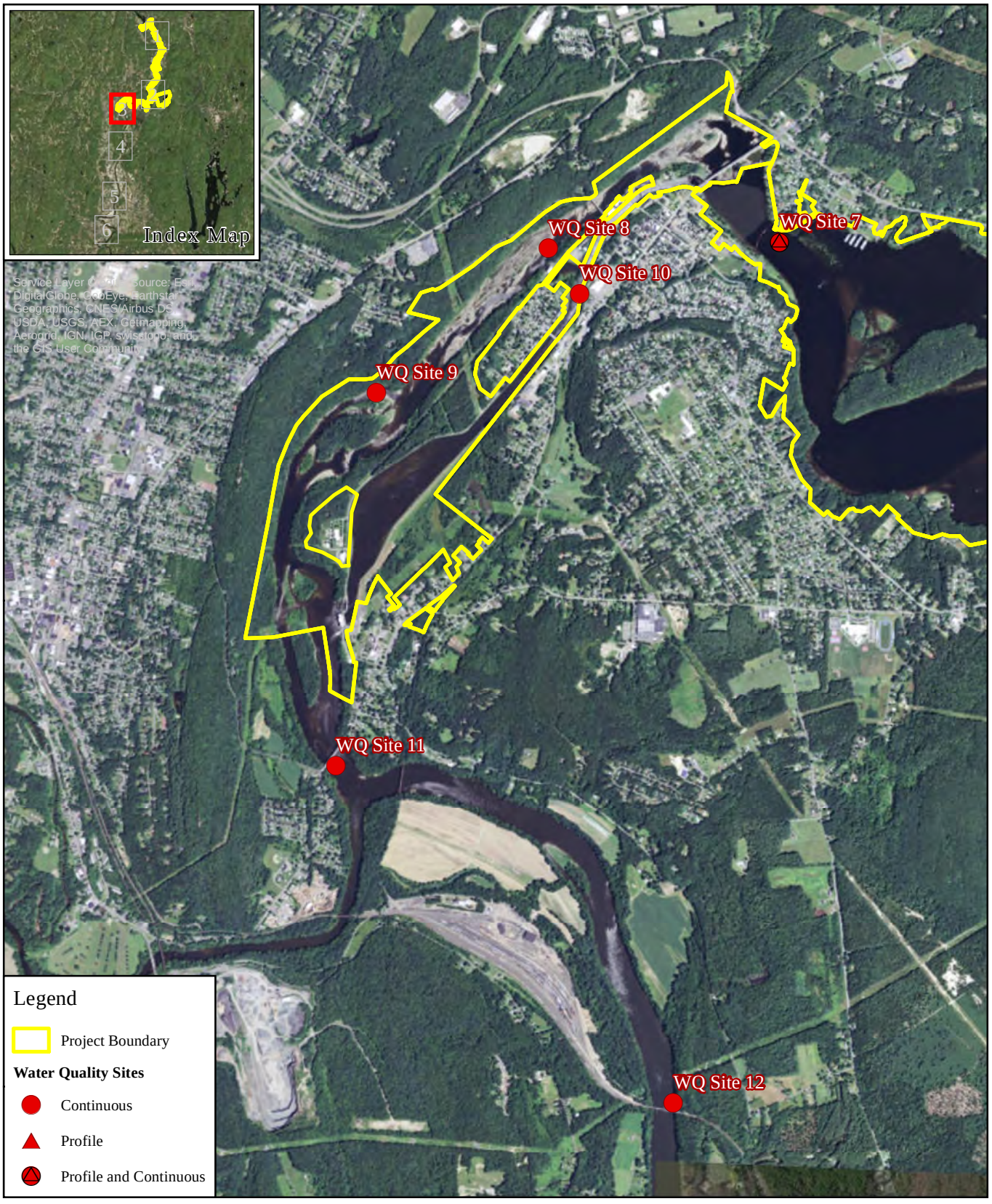
N

0 0.25 0.5 1 Miles

Figure 2.1-1:
Water Quality Sampling Locations

Map 2

Path: W:\gis\studies\3_2_1\maps\Figure_2_1_1.mxd



Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)
Relicensing Study 3.2.1

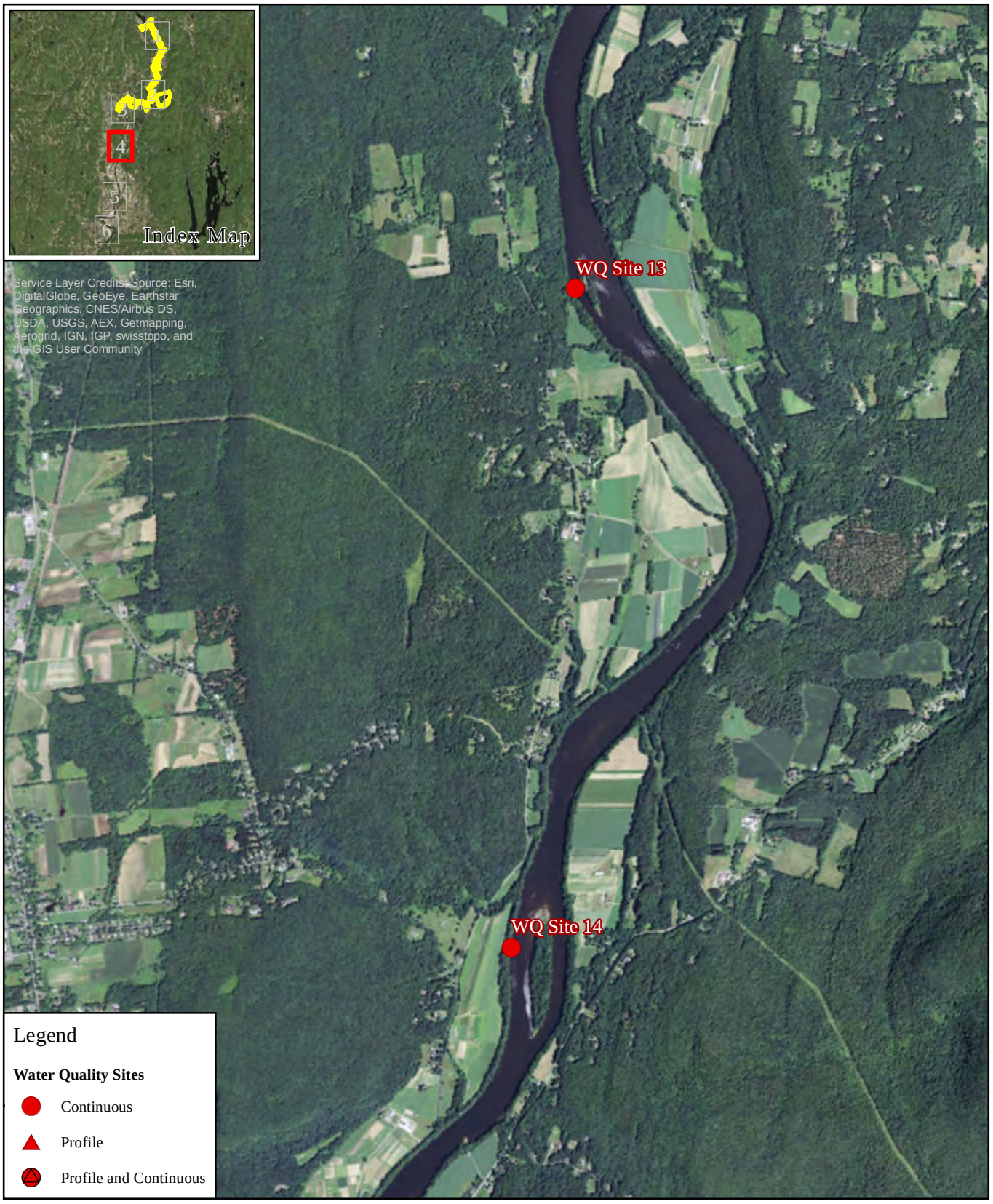
Figure 2.1-1:
Water Quality Sampling Locations

Map 3

N

0 0.25 0.5 1 Miles

Path: W:\gis\studies\3_2_1\maps\Figure_2_1_1.mxd



Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)
Relicensing Study 3.2.1

N

0 0.25 0.5 1 Miles

Figure 2.1-1:
Water Quality Sampling Locations

Map 4

Path: W:\gis\studies\3_2_1\maps\Figure_2_1_1.mxd

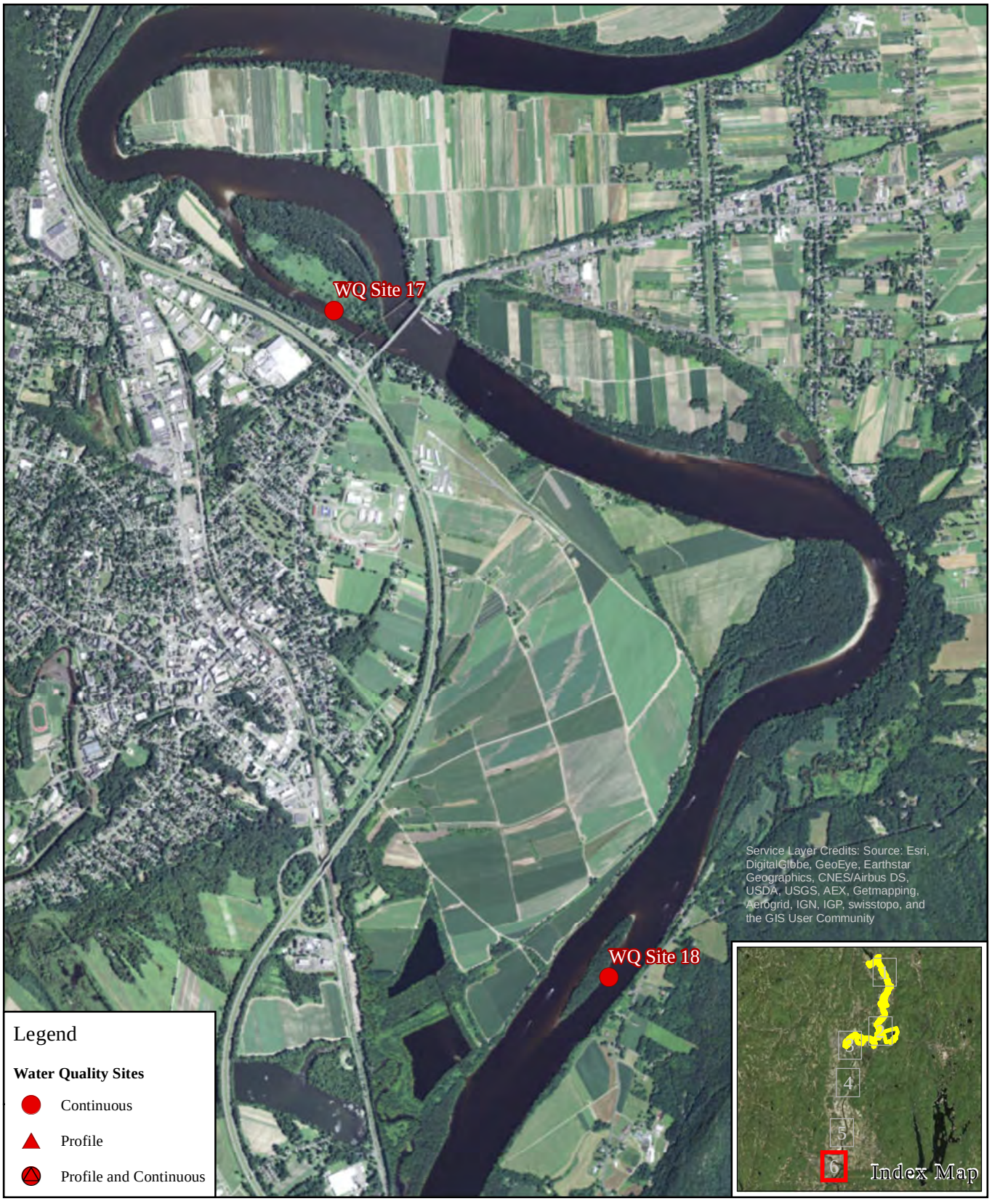
FirstLight
GDF SUEZ

Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)
Relicensing Study 3.2.1

Figure 2.1-1:
Water Quality Sampling Locations

Map 5

Path: W:\gis\studies\3_2_1\maps\Figure_2_1_1.mxd



FirstLight GDF SUEZ

Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)
Relicensing Study 3.2.1

N

0 0.25 0.5 1 Miles

Figure 2.1-1:
Water Quality Sampling Locations

Map 6

Path: W:\gis\studies\3_2_1\maps\Figure_2_1_1.mxd

3 RESULTS

3.1 2015 Weather and Flow Conditions

Water quality data collection occurred from April 2015 through mid-November 2015. Flow and weather conditions in the study area during the monitoring period were compared to long-term averages[3]. Box and whisker plots were used to present the weather conditions. Figure 3.1-1 displays the 2015 air temperature data against the long term medians based on daily average results. Figure 3.1-2 displays the 2015 precipitation data against the long term medians based on daily average results.

Typical weather conditions are represented within the box of the plot (i.e., between the 1st and 3rd quartile). More extreme weather conditions are represented within the whiskers of the plot (i.e., 1.5 times the interquartile range). Outlier data are represented by single data points either less than or greater than the range of data presented within the whiskers.

April and May 2015 experienced less precipitation in comparison to long-term averages. June was very wet and cool. The summer months of July and August had fairly typical conditions, as did October. September was warmer than usual and November was warmer and also drier than usual. August was the warmest month and November was the coolest month during the 2015 monitoring period.

Mean daily flow data, as measured on the Connecticut River at the Montague USGS Gage, were obtained for the monitoring period and compared to the long-term mean daily flow from 1975-2014[4] (see Figure 3.1-3). A wide range of flow conditions occurred during the monitoring period. Flows were generally highest in the spring and lowest in the summer months. April 2015 had the highest flows of the monitoring period due to snow melt. May 2015 was a dry month with low flows in comparison to long-term conditions. June 2015 had higher than normal flows due to precipitation events. Flows receded in July and remained low in August and September 2015, which had the lowest flows of the monitoring period, reflective of typical conditions. Overall, flow conditions during the 2015 field sampling effort followed the typical seasonal trend of high flows in the spring, low flows in the summer, and then increasing flows in the fall.

[3] Note that weather data was obtained from the Sunderland, MA weather station for precipitation and from the Greenfield, MA weather station for air temperature. The Sunderland weather station had historical data available for precipitation but not air temperature. The Sunderland precipitation data was used to discuss the most historical average available (i.e., 1979 – 2015). The Greenfield weather station had data from 2000 to 2015. The two weather stations are within approximately 10 miles of each other and less than 2 miles from the study area, making both sets of data representative of the study area conditions.

[4] Although the USGS Gage has been active since 1905, a more recent period was selected to reflect climate change and the development of flood control facilities in the basin above the Turners Falls Dam prior to 1975.

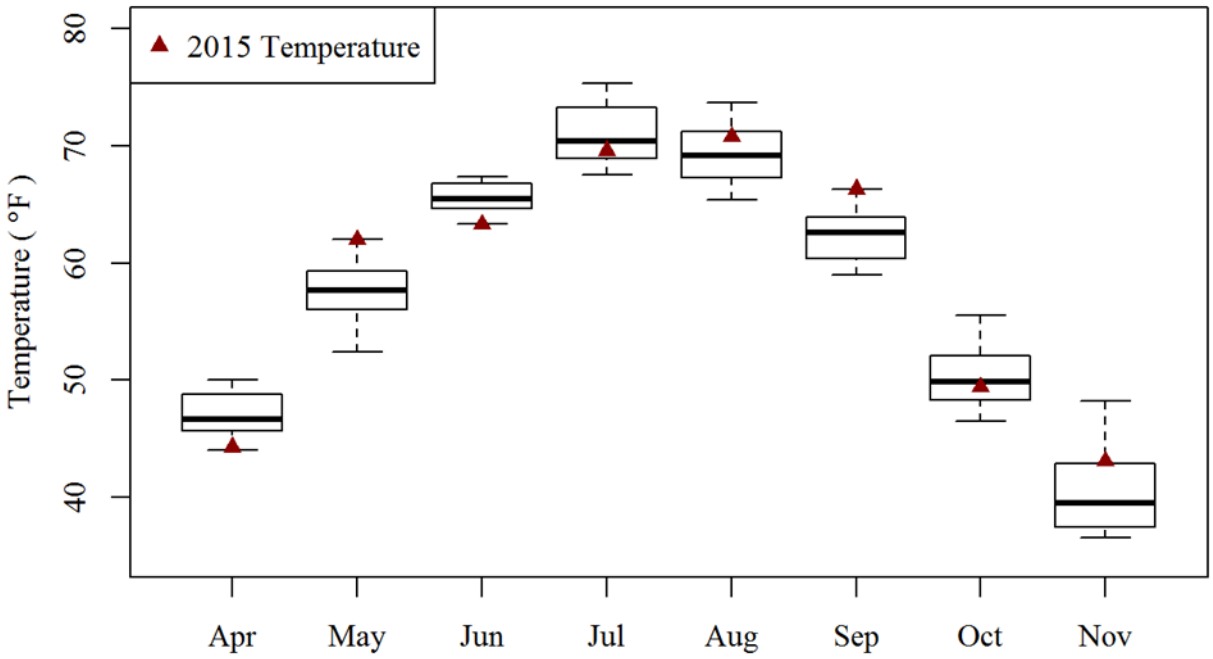


Figure 3.1-1: Long-Term Average Air Temperatures Compared to 2015 Average Air Temperatures by Month

Source: NOAA Online Weather Data. Monthly mean of daily average temperature (2000 – 2015) for Greenfield Station No. 3, MA.

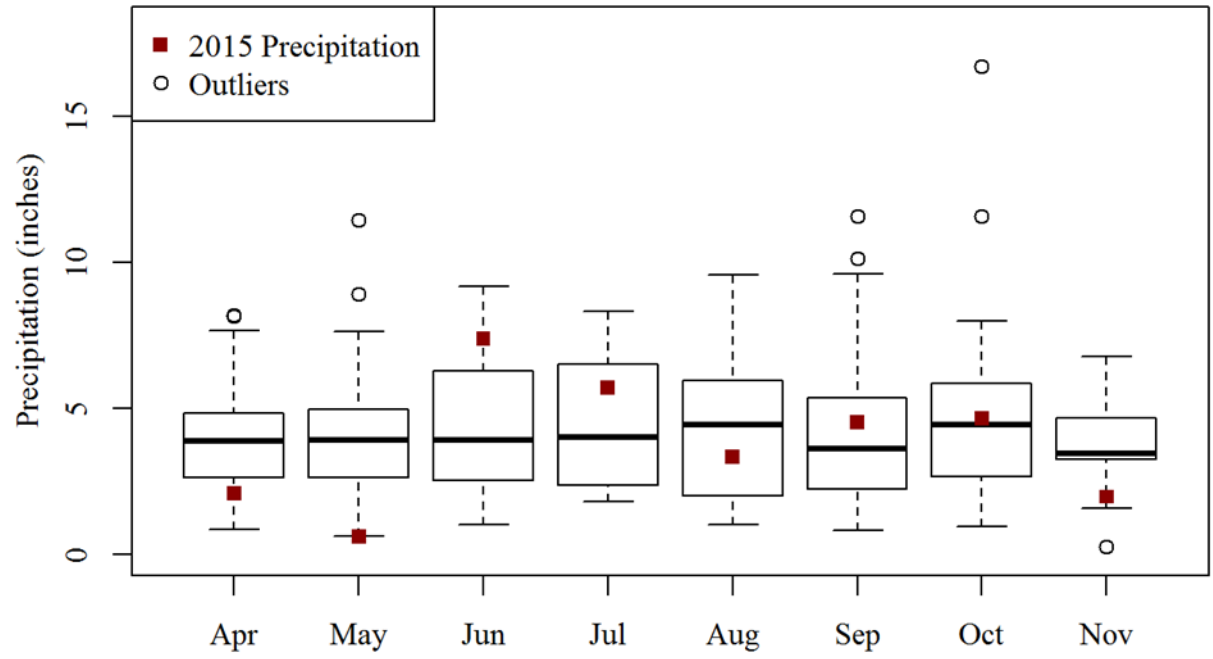


Figure 3.1-2: Long-Term Average Total Precipitation Compared to 2015 Total Precipitation by Month

Source: NOAA Online Weather Data. Monthly total average precipitation for Sunderland, MA (1979 – 2015).

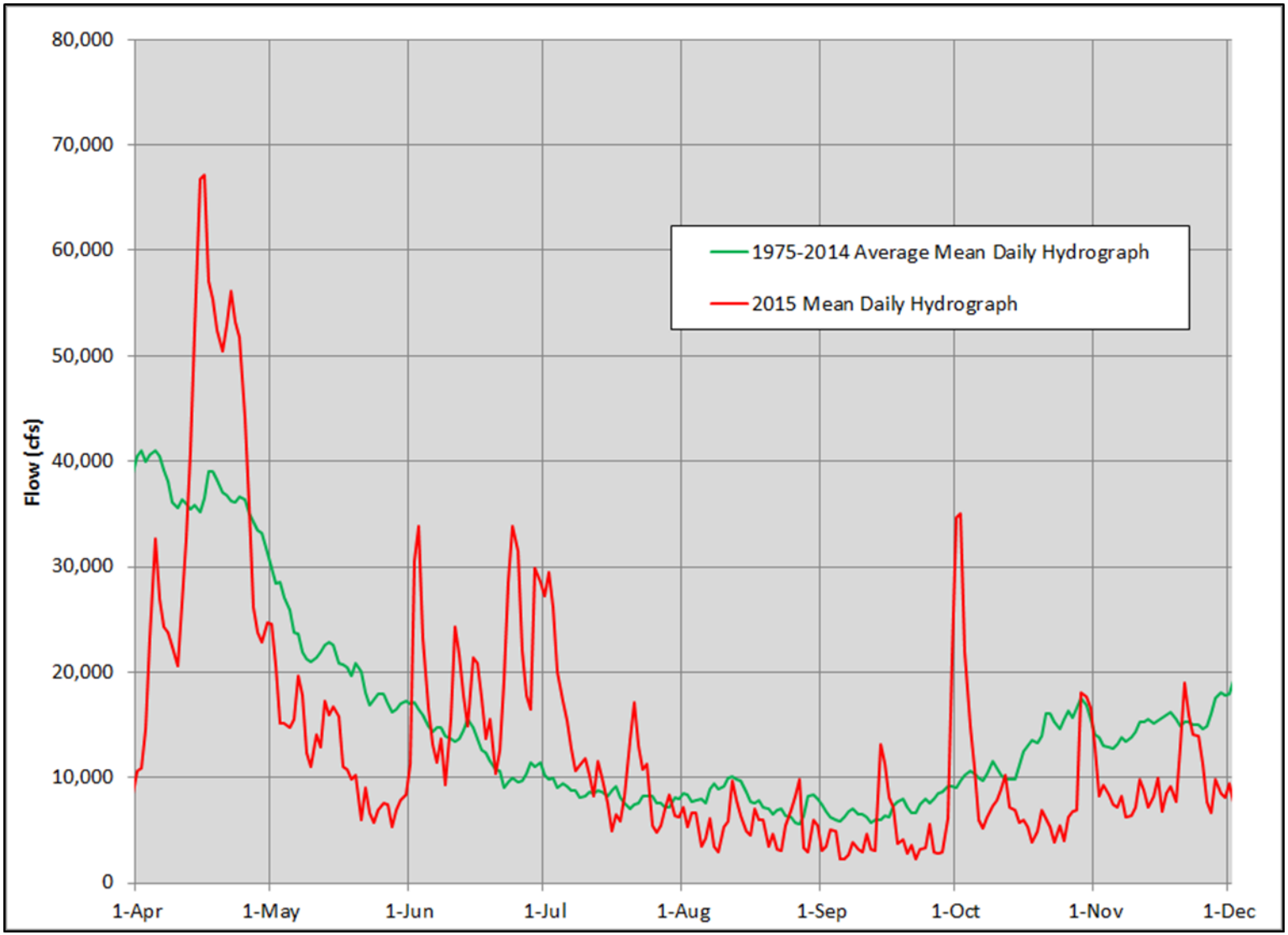


Figure 3.1-3: Connecticut River at Montague City, MA (USGS Gage No. 01170500), Comparison of Long Term Mean Daily Flows (1975-2014) versus 2015 Mean Daily Flows

3.2 Impoundment Vertical Profiles

Vertical DO and temperature profiles for each sampling event are shown in Figure 3.2-1 (temperature), Figure 3.2-2 (dissolved oxygen) and Figure 3.2-3 (DO percent saturation). The three locations observed within the TFI (i.e., Site 2, Site 6 and Site 7) were continuously well-mixed as the DO and temperature varied minimally between the water surface and deepest point of the profile. Supporting vertical profile data are contained in Tables 3.2-1 through 3.2-3. Isopleth charts for each vertical profile location and parameter are provided in Appendix D.

Water temperatures followed a typical seasonal pattern, gradually warming throughout the spring and summer. The highest measured temperatures at the three profile locations occurred during August and early September. The maximum temperature was 25.8°C measured at Site 7 on August 18. During this day, Site 7 temperatures only varied 0.3°C from top to bottom. Water temperatures were slightly cooler at upstream locations on this day (24.9°C throughout the water column at Site 2).

The DO concentrations showed a similar pattern of being uniform throughout the water column at each site. The minimum DO values recorded during the vertical profiles occurred during late August/early September. The minimum value recorded was 6.9 mg/L (83.2 %sat) from the deepest point of Site 7 on September 3. DO is inversely correlated with water temperature because colder water can hold more dissolved oxygen. DO concentrations at the three sites decreased in the warmer months of the summer and increased during the colder months of the spring and late fall.

Stratification of temperature and DO was not observed during the 2015 sampling period. The minimum, maximum and average differences observed between the surface and the bottom measurements for each location are provided in Table 3.2-4. The observed difference in temperature between the surface and bottom of the profile ranged from 0 to 0.9 °C among all sample locations. The average difference in temperature was 0.3°C or less for each location. A thermocline, indicating temperature stratification, is defined as a change of at least 1°C per meter of depth (Wetzel, 2001). The maximum difference from the top and bottom of the water column of 0.9°C was observed at Site 7; this change was a gradual reduction in temperature from top to bottom, rather than a distinct thermocline.

The observed difference in DO between the surface and the bottom of the profile was subtle, ranging from 0.1 to 0.8 mg/L, and from 1.4 to 10.8% saturation for the three locations. There was generally a slightly negative DO gradient as the depth increased at each location. The average difference in top to bottom DO was 0.5 mg/L or less for each location (see Table 3.2-4).

Table 3.2-1a. TFI Vertical Profile Results for 2015 - Deep Area Upstream of Northfield Mountain (Site 2) Temperature (°C)

Depth (m)	3-Apr	30-Apr	14-May	29-May	10-Jun	25-Jun	10-Jul	24-Jul	6-Aug	18-Aug	3-Sep	18-Sep	9-Oct	23-Oct	4-Nov	18-Nov
0	0.9	7.6	15.0	19.3	17.8	19.4	21.8	22.9	24.4	24.9	24.4	21.2	14.4	11.1	9.2	7.4
1	0.9	7.6	15.1	19.3	17.8	19.3	21.7	22.9	24.4	24.9	24.4	21.3	14.4	11.2	9.2	7.4
2	0.9	7.6	15.1	19.3	17.7	19.2	21.7	23.0	24.4	24.9	24.5	21.3	14.4	11.2	9.2	7.4
3	0.9	7.6	15.2	19.3	17.7	19.2	21.7	23.0	24.4	24.9	24.5	21.3	14.5	11.2	9.2	7.4
4	0.9	7.6	15.2	19.3	17.7	19.1	21.7	23.0	24.4	24.9	24.5	21.3	14.5	11.2	9.2	7.4
5	0.8	7.6	15.2	19.3	17.7	19.1	21.7	23.0	24.4	24.9	24.5	21.3	14.5	11.2	9.2	7.4
6	0.8	7.6	15.2	19.3	17.7	19.1	21.7	23.0	24.4	24.9	24.5	21.3	14.5	11.2	9.2	7.4
7	0.8	7.6	15.2	19.3	17.7	19.1	21.7	23.0	24.4	24.9	24.5	21.4	14.5	11.2	9.2	7.4
8	0.8	7.6	15.2	19.3	17.7	19.1	21.6	23.0	24.4	24.9	24.5	21.4	14.5	11.2	9.2	7.3
9	0.9	7.6	15.2	19.3	17.7	19.1	21.6	23.0	24.5	24.9	24.5	21.4	14.5	11.2	9.2	7.4
10	0.9	7.6	15.3	19.3	17.7	19.1	21.6	23.0	24.4	24.9	24.5	21.4	14.5	11.2	9.2	7.4
11	1.0	7.6	15.3	19.3	17.7	19.1	21.6	23.0	24.4	24.9	24.5	21.4	14.5	11.2	9.2	7.4
12	1.0	7.6	15.3	19.3	17.7	19.1	21.6	23.0	24.4	24.8	24.5	21.4	14.5	11.2	9.2	7.4
13	1.0	7.6	15.3	19.3	17.7	19.1	21.6	23.0	24.5	24.9	24.5	21.4	14.5	11.2	9.2	7.4
14	1.0	7.6	15.3	19.3	17.7	19.1	21.6	23.0	24.5	24.9	24.6	21.4	14.5	11.2	9.2	7.3
15	0.9	7.6	15.3	19.3	17.7	19.1	21.6	23.0	24.5	24.9	24.6	21.4	14.5	11.2	9.2	7.4
16	0.9	7.6	15.3	19.3	17.7	19.1	21.6	23.0	24.5	24.9	24.6		14.5		9.2	7.4
17	1.0	7.6	15.3	19.3	17.7	19.1	21.6	23.0	24.5	24.9	24.6		14.5		9.2	7.3
18	1.0	7.6	15.3	19.3	17.7	19.1	21.6	23.0	24.5	24.9	24.6		14.5		9.2	7.3
19	0.9	7.6	15.3	19.3	17.7	19.1	21.6	23.0	24.5	24.9	24.6		14.5		9.2	7.3
20	1.0	7.6	15.3	19.3	17.7	19.1		23.0		24.9			14.5		9.2	7.3
21	1.0	7.6	15.3	19.3	17.7	19.1		23.0							9.2	7.3
22		7.6	15.3			19.1										
23						19.1										

Table 3.2-1b. TFI Vertical Profile Results for 2015 - Deepest Area of TFI (Site 6) Temperature (°C)

Depth (m)	3-Apr	30-Apr	14-May	29-May	10-Jun	25-Jun	10-Jul	24-Jul	6-Aug	18-Aug	3-Sep	18-Sep	9-Oct	23-Oct	4-Nov	18-Nov
0	1.9	7.8	15.6	19.2	17.7	Site inaccessible due to high flows.	21.7	23.3	25.0	25.3	24.6	22.7	15.0	11.8	9.3	7.4
1	1.8	7.8	15.7	19.2	17.8		21.6	23.4	25.1	25.4	24.8	22.8	15.0	11.9	9.3	7.4
2	1.8	7.8	15.7	19.3	17.8		21.5	23.4	25.1	25.4	24.8	22.8	15.0	11.9	9.3	7.4
3	1.8	7.8	15.7	19.3	17.8		21.5	23.5	25.1	25.4	24.9	22.8	15.0	11.9	9.3	7.4
4	1.8	7.8	15.7	19.3	17.8		21.5	23.5	25.1	25.4	24.9	22.8	15.0	11.9	9.3	7.4
5	1.7	7.8	15.7	19.3	17.8		21.5	23.5	25.2	25.4	24.9	22.8	15.0	12.0	9.3	7.4
6	1.8	7.8	15.7	19.3	17.8		21.5	23.6	25.2	25.4	24.9	22.8	15.0	11.9	9.3	7.4
7	1.7	7.8	15.7	19.3	17.8		21.5	23.5	25.2	25.4	24.9	22.8	15.0	12.0	9.3	7.4
8	1.7	7.8	15.7	19.3	17.8		21.5	23.5	25.2	25.4	24.9	22.8	15.1	12.0	9.3	7.5
9	1.7	7.8	15.7	19.3	17.8		21.5	23.5	25.2	25.4	24.9	22.9	15.1	12.0	9.3	7.5
10	1.7	7.8	15.7	19.3	17.8		21.5	23.6	25.2	25.5	24.9	22.9	15.1	12.0	9.3	7.4
11	1.7	7.8	15.7	19.3	17.8		21.5	23.6	25.2	25.5	24.9	22.9	15.1	12.0	9.3	7.4
12	1.7	7.7	15.7	19.3	17.8		21.5	23.6	25.2	25.5	25.0	22.9	15.1	12.0	9.3	7.4
13	1.7	7.7	15.7	19.3	17.8		21.4	23.6	25.2	25.5	25.0	22.9	15.1	12.0	9.3	7.4
14	1.7	7.7	15.7	19.3	17.8		21.4	23.6	25.2	25.5	25.0	22.9	15.1	12.0	9.3	7.4
15	1.7	7.7	15.7	19.3	17.8		21.4	23.6	25.2	25.5	25.0	22.9	15.1	12.0	9.3	7.4
16	1.7	7.7	15.7	19.3	17.8		21.4	23.6	25.2	25.5	25.0	22.9	15.1	12.0	9.3	7.4
17	1.7	7.7	15.7	19.3	17.8		21.5	23.6	25.2	25.5	25.0	22.9	15.1	12.0	9.3	7.5
18	1.7	7.7	15.7	19.3	17.8		21.5	23.6	25.2	25.5	25.0	22.9	15.1	12.0	9.3	7.4
19	1.7	7.7	15.7	19.3	17.8		21.5	23.6	25.3	25.5	25.0	22.9	15.1	12.0	9.3	7.5
20	1.7	7.7	15.7	19.3	17.8		21.5	23.6	25.2	25.5	25.0	22.9	15.1	12.0	9.3	7.5
21	1.7	7.7	15.7	19.3	17.8		21.5	23.6	25.2	25.5	25.0	22.9	15.1	12.0	9.4	7.5
22	1.7	7.7	15.7	19.3	17.8		21.5	23.6	25.2	25.5	25.0	22.9	15.1	12.0	9.4	7.5
23	1.7	7.7	15.7	19.3	17.8		21.5	23.6	25.2	25.5	25.0	22.9	15.1	12.0	9.4	7.5
24	1.7	7.7	15.7	19.3	17.8		21.5	23.6	25.3	25.5	25.0	22.9	15.1	12.0	9.4	7.5
25	1.7	7.7	15.7	19.3	17.8		21.5	23.6	25.3	25.5	25.0	22.9	15.1	12.0	9.4	7.5
26	1.7	7.7	15.7	19.3	17.8		21.4	23.6	25.2	25.5	25.0	22.9	15.1	12.0	9.4	7.5
27	1.7	7.7	15.7	19.3	17.8		21.5	23.6	25.2	25.5	25.0	22.9	15.1	12.0	9.4	7.5
28	1.7	7.7	15.7	19.3	17.8		21.5	23.6	25.2	25.5	25.0	22.9	15.1	12.0	9.4	7.5
29	1.7	7.7	15.7	19.3	17.8		21.5	23.6	25.2	25.5	25.0	22.9	15.1			7.5
30	1.7	7.7	15.7	19.3	17.8		21.5	23.6	25.2	25.5	25.0	22.9	15.1			7.5
31	1.7			19.3	17.8			23.6	25.2		25.0	22.9	15.1			7.5
32	1.7			19.3	17.8			23.6	25.2		25.0	22.9				7.5
33				19.3	17.8		21.5	23.6	25.2		25.0	22.9				7.4
34				19.3					25.2		25.0	22.9				7.5
35				19.3												

Table 3.2-1c. TFI Vertical Profile Results for 2015 Upstream of Turners Falls Dam & Boat Barrier (Site 7) Temperature (°C)

Depth (m)	3-Apr	30-Apr	14-May	29-May	10-Jun	25-Jun	10-Jul	24-Jul	6-Aug	18-Aug	3-Sep	18-Sep	9-Oct	23-Oct	4-Nov	11-Nov
0	Site inaccessible due to ice.	Site inaccessible due to high flows.	16.3	20.3	17.8	Site inaccessible due to high flows.	21.9	23.9	25.0	25.8	25.0	22.5	14.9	11.8	9.7	10.2
1			16.1	20.2	17.7		21.9	24.0	25.1	25.8	25.1	22.7	15.1	11.8	9.8	10.0
2			16.0	19.7	17.7		21.9	24.1	25.2	25.8	25.0	22.8	15.1	11.8	9.8	10.0
3			16.0	19.6	17.7		21.8	24.0	25.2	25.7	25.0	22.8	15.0	11.8	9.8	9.9
4			16.0	19.6	17.7		21.8	24.1	25.2	25.6	25.0	22.9	15.0	11.8	9.8	9.9
5			15.9	19.5	17.7		21.8	24.1	25.2	25.6	25.0	22.9	15.0	11.8	9.8	9.9
6			15.9	19.5	17.7		21.8	24.1	25.2	25.6	25.0	22.9	15.0	11.8	9.8	9.9
7			15.9	19.5	17.7		21.7	24.1	25.2	25.5	25.0	22.8	15.0	11.8	9.8	9.9
8			15.9	19.5	17.7		21.7	24.1	25.2	25.5	25.0	22.8	15.0	11.8	9.8	9.9
9			15.9	19.5	17.7		21.7	24.1	25.2	25.5	25.0	22.8	15.0	11.8	9.8	9.9
10			15.9	19.5	17.7		21.7	24.1	25.2	25.5	24.9	22.8	15.0	11.8	9.8	9.9
11			15.9	19.5	17.7		21.7	24.1	25.2	25.5	24.8	22.8	15.0	11.8	9.8	9.9
12			15.9	19.5	17.7		21.7	24.1	25.2	25.5	24.8	22.8	15.0	11.8	9.8	9.9
13			15.9	19.4	17.7		21.7	24.1	25.2	25.5	24.8	22.8	15.0		9.8	9.9
14			15.9	19.3	17.7											
15			15.9	19.4	17.7											
16			15.9	19.4												
17			15.9													
18			15.9													

Table 3.2-2a. TFI Vertical Profile Results for 2015 – Deep Area Upstream of Northfield Mountain (Site 2) Dissolved Oxygen (mg/L)

Depth (m)	3-Apr	30-Apr	14-May	29-May	10-Jun	25-Jun	10-Jul	24-Jul	6-Aug	18-Aug	3-Sep	18-Sep	9-Oct	23-Oct	4-Nov	18-Nov
0	13.96	12.39	10.03	9.30	9.78	9.91	8.49	8.15	7.57	7.59	7.66	8.12	9.45	9.94	11.04	11.91
1	14.02	12.31	9.97	9.28	9.79	9.93	8.50	8.14	7.56	7.58	7.64	8.08	9.43	9.86	11.02	11.90
2	14.04	12.36	9.95	9.27	9.80	9.91	8.49	8.11	7.55	7.60	7.61	8.05	9.41	9.80	11.00	11.88
3	14.04	12.36	9.91	9.25	9.80	9.86	8.48	8.10	7.55	7.58	7.58	8.01	9.37	9.76	10.98	11.87
4	14.05	12.36	9.90	9.23	9.79	9.86	8.46	8.08	7.53	7.57	7.57	8.01	9.35	9.80	10.96	11.84
5	14.03	12.35	9.88	9.22	9.79	9.85	8.45	8.06	7.52	7.52	7.56	7.98	9.34	9.86	10.94	11.83
6	14.03	12.35	9.87	9.19	9.78	9.83	8.44	8.04	7.50	7.50	7.54	7.96	9.32	9.79	10.93	11.81
7	14.02	12.34	9.84	9.18	9.77	9.82	8.44	8.03	7.48	7.53	7.53	7.94	9.31	9.84	10.90	11.80
8	14.01	12.33	9.84	9.16	9.76	9.80	8.42	8.01	7.47	7.46	7.52	7.92	9.29	9.85	10.89	11.83
9	14.00	12.33	9.82	9.15	9.75	9.81	8.40	8.00	7.44	7.50	7.51	7.92	9.28	9.81	10.87	11.77
10	13.96	12.31	9.79	9.14	9.75	9.81	8.39	7.98	7.45	7.44	7.51	7.90	9.27	9.76	10.86	11.76
11	13.90	12.32	9.77	9.12	9.74	9.78	8.38	7.97	7.43	7.43	7.50	7.87	9.25	9.73	10.84	11.74
12	13.88	12.30	9.76	9.11	9.75	9.76	8.36	7.95	7.42	7.41	7.49	7.86	9.24	9.77	10.82	11.72
13	13.86	12.30	9.74	9.09	9.75	9.74	8.34	7.93	7.39	7.44	7.47	7.84	9.22	9.78	10.81	11.71
14	13.84	12.27	9.73	9.08	9.72	9.76	8.33	7.92	7.37	7.40	7.46	7.83	9.20	9.77	10.79	11.72
15	13.83	12.27	9.73	9.06	9.67	9.74	8.31	7.91	7.35	7.39	7.45	7.82	9.19	9.77	10.77	11.69
16	13.81	12.25	9.72	9.05	9.68	9.72	8.30	7.90	7.35	7.37	7.43		9.17		10.75	11.67
17	13.78	12.24	9.72	9.03	9.66	9.70	8.29	7.88	7.34	7.36	7.42		9.15		10.73	11.69
18	13.76	12.25	9.72	9.02	9.64	9.70	8.27	7.87	7.33	7.35	7.41		9.14		10.72	11.67
19	13.73	12.22	9.70	9.00	9.62	9.70	8.26	7.85	7.32	7.34	7.40		9.12		10.69	11.60
20	13.70	12.20	9.69	8.99	9.61	9.68		7.83		7.33			9.11		10.68	11.64
21	13.68	12.18	9.70	8.97	9.57	9.65		7.85							10.67	11.62
22		12.18	9.69			9.64										
23						9.61										

Table 3.2-2b. TFI Vertical Profile Results for 2015 – Deepest area of TFI (Site 6) Dissolved Oxygen (mg/L)

Depth (m)	3-Apr	30-Apr	14-May	29-May	10-Jun	25-Jun	10-Jul	24-Jul	6-Aug	18-Aug	3-Sep	18-Sep	9-Oct	23-Oct	4-Nov	18-Nov
0	13.78	12.19	9.78	9.23	9.29	Site inaccessible due to high flows.	8.58	8.33	7.63	8.02	7.60	7.99	9.75	10.34	10.90	11.94
1	13.78	12.19	9.69	9.20	9.29		8.60	8.29	7.60	7.98	7.54	7.95	9.72	10.31	10.89	11.94
2	13.78	12.18	9.67	9.17	9.26		8.61	8.25	7.58	7.96	7.53	7.93	9.69	10.28	10.87	11.91
3	13.75	12.16	9.65	9.15	9.24		8.59	8.24	7.57	7.96	7.49	7.92	9.68	10.26	10.85	11.9
4	13.73	12.14	9.63	9.13	9.23		8.57	8.22	7.55	7.94	7.48	7.90	9.66	10.22	10.83	11.89
5	13.75	12.13	9.62	9.12	9.22		8.55	8.21	7.52	7.92	7.46	7.89	9.65	10.19	10.82	11.83
6	13.71	12.11	9.61	9.10	9.20		8.53	8.18	7.51	7.91	7.45	7.87	9.63	10.23	10.80	11.84
7	13.70	12.10	9.59	9.09	9.18		8.52	8.18	7.50	7.89	7.44	7.86	9.61	10.15	10.78	11.82
8	13.71	12.08	9.58	9.07	9.17		8.53	8.16	7.48	7.88	7.42	7.83	9.57	10.14	10.76	11.74
9	13.70	12.07	9.56	9.06	9.16		8.51	8.15	7.47	7.87	7.41	7.81	9.56	10.12	10.74	11.72
10	13.68	12.06	9.55	9.04	9.14		8.49	8.12	7.46	7.85	7.39	7.80	9.56	10.10	10.72	11.76
11	13.66	12.04	9.54	9.03	9.13		8.47	8.11	7.44	7.83	7.38	7.79	9.53	10.08	10.70	11.74
12	13.64	12.04	9.54	9.01	9.12		8.45	8.10	7.43	7.81	7.35	7.77	9.50	10.06	10.69	11.72
13	13.58	12.02	9.52	8.99	9.11		8.43	8.09	7.41	7.80	7.34	7.76	9.48	10.03	10.67	11.69
14	13.56	12.01	9.54	8.97	9.10		8.44	8.08	7.41	7.79	7.33	7.75	9.46	10.02	10.66	11.68
15	13.54	11.99	9.54	8.96	9.09		8.41	8.05	7.39	7.78	7.32	7.74	9.45	10.00	10.64	11.68
16	13.54	11.97	9.52	8.95	9.07		8.40	8.04	7.38	7.76	7.31	7.73	9.43	9.99	10.62	11.62
17	13.50	11.95	9.52	8.93	9.06		8.37	8.03	7.36	7.75	7.30	7.71	9.41	9.98	10.58	11.57
18	13.49	11.94	9.52	8.92	9.05		8.39	8.02	7.35	7.74	7.29	7.70	9.40	9.96	10.58	11.54
19	13.48	11.93	9.50	8.90	9.04		8.37	8.01	7.32	7.72	7.27	7.68	9.38	9.95	10.57	11.51
20	13.45	11.99	9.50	8.89	9.02		8.36	8.00	7.33	7.71	7.26	7.67	9.37	9.93	10.55	11.49
21	13.42	11.99	9.48	8.88	9.00		8.35	7.98	7.31	7.68	7.25	7.65	9.36	9.91	10.50	11.48
22	13.42	11.99	9.46	8.86	8.99		8.33	7.97	7.30	7.68	7.24	7.63	9.34	9.89	10.48	11.46
23	13.39	11.99	9.46	8.85	8.97		8.31	7.95	7.29	7.67	7.22	7.62	9.32	9.88	10.45	11.43
24	13.37	11.99	9.45	8.83	8.96		8.28	7.94	7.27	7.66	7.20	7.61	9.31	9.86	10.44	11.42
25	13.34	11.99	9.44	8.82	8.95		8.27	7.93	7.25	7.65	7.19	7.60	9.30	9.84	10.42	11.42
26	13.32	11.99	9.44	8.80	8.92		8.27	7.92	7.25	7.64	7.18	7.59	9.27	9.83	10.40	11.4
27	13.20	11.99	9.44	8.79	8.91		8.24	7.91	7.24	7.62	7.17	7.57	9.26	9.80	10.39	11.38
28	13.20	11.99	9.43	8.77	8.91		8.23	7.91	7.23	7.61	7.16	7.56	9.25	9.75	10.38	11.36
29	13.20	11.99	9.42	8.76	8.89		8.22	7.88	7.22	7.60	7.15	7.56	9.23			11.35
30	13.20	11.92	9.41	8.75	8.89		8.22	7.86	7.21	7.56	7.14	7.54	9.21			11.34
31	13.20			8.73	8.88			7.86	7.19		7.13	7.52	9.19			11.33
32	13.20			8.72	8.88			7.85	7.18		7.12	7.50				11.3
33				8.71	8.88			7.84	7.16		7.11	7.49				11.33
34				8.70					7.14		7.08	7.48				11.32
35				8.68												

Table 3.2-2c. TFI Vertical Profile Results for 2015 – Upstream of Turners Falls Dam & Boat Barrier (Site 7) Dissolved Oxygen (mg/L)

Depth (m)	3-Apr	30-Apr	14-May	29-May	10-Jun	25-Jun	10-Jul	24-Jul	6-Aug	18-Aug	3-Sep	18-Sep	9-Oct	23-Oct	4-Nov	11-Nov
0	Site inaccessible due to ice.	Site inaccessible due to high flows.	9.61	8.92	9.34	Site inaccessible due to high flows.	8.59	8.17	7.79	8.40	7.70	8.30	9.77	10.16	10.96	10.81
1			9.66	8.83	9.28		8.58	8.14	7.78	8.41	7.75	8.20	9.69	10.15	10.90	10.84
2			9.66	9.07	9.26		8.56	8.11	7.74	8.33	7.52	8.16	9.68	10.11	10.86	10.82
3			9.64	9.08	9.23		8.55	8.05	7.71	8.10	7.45	8.15	9.67	10.10	10.83	10.81
4			9.63	9.06	9.20		8.53	8.06	7.70	7.96	7.43	8.11	9.62	10.12	10.80	10.78
5			9.63	9.05	9.18		8.50	7.99	7.69	7.88	7.32	8.10	9.55	10.11	10.77	10.74
6			9.62	9.02	9.18		8.47	7.97	7.68	7.86	7.29	8.08	9.51	10.11	10.75	10.74
7			9.61	8.99	9.17		8.45	7.96	7.66	7.84	7.25	7.93	9.49	10.11	10.71	10.71
8			9.60	8.96	9.15		8.44	7.95	7.65	7.83	7.24	7.85	9.49	10.10	10.68	10.70
9			9.59	8.94	9.14		8.42	7.93	7.62	7.83	7.15	7.83	9.47	10.08	10.64	10.69
10			9.57	8.91	9.13		8.40	7.92	7.61	7.82	7.03	7.81	9.44	10.03	10.62	10.67
11			9.56	8.91	9.11		8.36	7.90	7.60	7.76	7.03	7.84	9.42	10.01	10.59	10.62
12			9.55	8.90	9.09		8.28	7.89	7.58	7.74	7.01	7.86	9.41	9.99	10.57	10.59
13			9.55	8.87	9.07		8.27	7.88	7.57	7.71	6.90	7.80	9.39		10.56	10.58
14			9.53	8.86	9.05											
15			9.53	8.82	9.03											
16			9.52	8.81												
17			9.51													
18			9.50													

Table 3.2-3a. TFI Vertical Profile Results for 2015 – Deep Area Upstream of Northfield Mountain (Site 2)
Dissolved Oxygen Percent Saturation

Depth (m)	3-Apr	30-Apr	14-May	29-May	10-Jun	25-Jun	10-Jul	24-Jul	6-Aug	18-Aug	3-Sep	18-Sep	9-Oct	23-Oct	4-Nov	18-Nov
0	98.0	103.6	99.4	100.9	102.9	107.7	96.7	94.9	90.6	91.7	91.7	91.4	92.6	90.5	96.0	99.1
1	98.4	103.0	99.1	100.7	103.0	107.6	96.6	94.7	90.5	91.6	91.9	91.1	92.3	89.5	95.8	99.0
2	98.4	103.4	98.9	100.5	102.9	107.3	96.6	94.5	90.4	91.8	91.2	90.8	92.1	89.3	95.6	98.9
3	98.5	103.4	98.7	100.3	102.9	106.6	96.4	94.4	90.3	91.5	90.9	90.3	91.9	88.9	95.5	98.7
4	98.3	103.4	98.6	100.1	102.8	106.5	96.2	94.2	90.1	91.4	90.8	90.4	91.7	89.4	95.2	98.5
5	98.2	103.3	98.4	100.0	102.8	106.4	96.1	94.0	89.9	90.8	90.6	90.0	91.6	89.7	95.1	98.4
6	98.1	103.3	98.3	99.7	102.7	106.2	95.9	93.7	89.7	90.5	90.4	89.7	91.4	89.4	94.9	98.3
7	98.1	103.2	98.0	99.5	102.6	106.0	95.7	93.6	89.5	91.0	90.3	89.7	91.3	89.7	94.8	98.2
8	98.0	103.1	98.0	99.4	102.4	105.9	95.5	93.4	89.3	90.0	90.1	89.5	91.1	89.7	94.6	98.2
9	97.9	103.0	97.8	99.2	102.3	105.9	95.3	93.2	89.1	90.5	90.0	89.5	91.0	89.4	94.5	98.0
10	97.8	102.9	97.7	99.1	102.3	105.9	95.2	93.0	89.1	89.8	90.1	89.2	90.9	88.9	94.4	97.8
11	97.7	103.0	97.5	98.9	102.2	105.7	95.0	92.8	88.9	89.8	89.9	89.0	90.7	88.6	94.2	97.7
12	97.5	102.8	97.4	98.8	102.4	105.4	94.8	92.6	88.8	89.6	89.8	88.8	90.6	89.3	94.0	97.5
13	97.4	102.9	97.3	98.6	102.3	105.3	94.7	92.5	88.6	89.8	89.8	88.7	90.4	89.1	93.9	97.4
14	97.1	102.5	97.1	98.4	102.0	105.5	94.5	92.3	88.5	89.4	89.6	88.5	90.2	89.1	93.7	97.5
15	97.0	102.6	97.1	98.3	101.5	105.3	94.3	92.2	88.4	89.2	89.5	88.3	90.1	89.1	93.6	97.2
16	96.9	102.4	97.0	98.1	101.5	105.0	94.2	92.0	88.2	89.0	89.3		89.9		93.4	97.1
17	96.9	102.3	97.0	97.9	101.3	104.8	94.0	91.9	88.0	88.9	89.1		89.8		93.3	97.0
18	96.7	102.4	97.0	97.8	101.1	104.8	93.9	91.7	87.9	88.7	89.0		89.6		93.1	96.9
19	96.5	102.1	96.9	97.6	101.0	104.8	93.7	91.5	87.7	88.6	88.8		89.5		92.9	96.6
20	96.4	102.0	96.7	97.5	100.8	104.5		91.4		88.5			89.3		92.8	96.6
21	96.2	101.8	96.8	97.2	100.5	104.2		91.2							92.7	96.4
22		101.8	96.7			104.1										
23						103.8										

Table 3.2-3b. TFI Vertical Profile Results for 2015 – Deepest Area of TFI (Site 6) Dissolved Oxygen Percent Saturation

Depth (m)	3-Apr	30-Apr	14-May	29-May	10-Jun	25-Jun	10-Jul	24-Jul	6-Aug	18-Aug	3-Sep	18-Sep	9-Oct	23-Oct	4-Nov	18-Nov
0	99.1	102.5	98.1	99.8	97.7		97.6	97.6	92.3	97.6	91.4	92.6	96.4	95.6	95.0	99.4
1	99.1	102.4	97.5	99.6	97.7		97.6	97.4	92.1	97.3	91.0	92.3	96.3	95.4	94.9	99.3
2	99.1	102.3	97.3	99.4	97.4		97.5	97.1	91.9	97.1	90.7	92.1	96.1	95.1	94.7	99.1
3	98.8	102.2	97.1	99.2	97.2		97.3	96.9	91.7	96.9	90.5	91.9	96.0	94.9	94.5	99.0
4	98.7	102.0	96.9	99.0	97.1		97.1	96.8	91.5	96.7	90.3	91.7	95.8	94.7	94.4	98.9
5	98.6	101.9	96.8	98.9	96.9		96.8	96.6	91.3	96.6	90.0	91.6	95.7	94.5	94.2	98.4
6	98.6	101.8	96.7	98.7	96.8		96.7	96.5	91.2	96.4	90.0	91.4	95.5	94.6	94.1	98.5
7	98.5	101.6	96.6	98.5	96.6		96.5	96.2	91.0	96.2	89.8	91.2	95.3	94.2	93.9	98.3
8	98.3	101.5	96.5	98.3	96.5		96.6	96.1	90.9	96.1	89.6	91.0	95.1	94.0	93.7	97.9
9	98.2	101.4	96.2	98.2	96.3		96.4	95.9	90.7	95.9	89.5	90.9	94.9	93.9	93.6	97.7
10	98.1	101.3	96.1	98.0	96.1		96.2	95.8	90.6	95.7	89.3	90.7	94.8	93.7	93.4	97.9
11	97.9	101.1	96.1	97.9	96.0		95.9	95.6	90.4	95.6	89.1	90.6	94.6	93.5	93.3	97.6
12	97.9	100.9	96.0	97.7	95.9		95.6	95.5	90.2	95.4	89.0	90.4	94.4	93.3	93.1	97.5
13	97.4	100.7	96.0	97.5	95.9		95.4	95.3	90.1	95.3	88.9	90.2	94.2	93.1	93.0	97.3
14	97.2	100.6	96.0	97.3	95.7		95.3	95.2	90.0	95.1	88.7	90.1	94.0	93.0	92.9	97.2
15	97.1	100.5	95.9	97.2	95.6		95.1	94.9	89.7	95.0	88.6	90.0	93.9	92.8	92.7	97.2
16	97.1	100.3	95.8	97.0	95.4		95.0	94.7	89.6	94.8	88.5	89.0	93.7	92.7	92.5	96.9
17	96.8	100.2	95.8	96.9	95.3		94.8	94.6	89.4	94.7	88.4	89.7	93.6	92.6	92.4	96.4
18	96.7	100.1	95.8	96.7	95.1		94.9	94.5	89.3	94.5	88.2	89.5	93.4	92.4	92.2	96.5
19	96.7	99.9	95.7	96.5	95.1		94.8	94.4	89.1	94.3	88.0	89.4	93.2	92.3	92.1	96.3
20	96.5	100.5	95.6	96.4	94.9		94.6	94.2	89.0	94.2	87.8	89.2	93.1	92.1	91.9	96.0
21	96.2	100.5	95.4	96.3	94.7		94.6	94.1	88.8	93.9	87.7	89.0	93.0	91.9	91.7	95.9
22	96.2	100.5	95.2	96.1	94.5		94.3	93.9	88.7	93.8	87.6	88.8	92.8	91.8	91.5	95.8
23	96.0	100.5	95.2	95.9	94.3		94.1	93.8	88.6	93.7	87.4	88.6	92.7	91.6	91.2	95.5
24	95.9	100.5	95.1	95.8	94.2		93.8	93.7	88.4	93.5	87.2	88.5	92.5	91.5	91.1	95.4
25	95.7	100.5	95.0	95.6	94.1		93.6	93.5	88.3	93.4	87.1	88.3	92.4	91.3	91.0	95.2
26	95.6	100.5	95.1	95.5	93.8		93.5	93.3	88.1	93.3	86.9	88.2	92.2	91.2	90.9	95.0
27	94.6	100.5	95.1	95.3	93.7		93.3	93.2	88.0	93.1	86.8	88.1	92.0	90.9	90.7	94.9
28	94.6	100.5	95.0	95.1	93.7		93.2	93.2	87.8	92.9	86.6	88.0	91.9	90.5	90.6	94.8
29	94.6	100.5	94.8	95.0	93.5		93.0	92.9	87.7	92.8	86.6	87.9	91.7			94.7
30	94.6	99.9	94.7	94.9	93.5		93.1	92.6	87.5	92.3	86.4	87.7	91.6			94.6
31	94.6			94.7	93.4			92.6	87.4		86.3	87.4	91.3			94.5
32	94.6			94.6	93.4			92.6	87.2		86.1	87.3				94.3
33				94.5	93.4		92.8	92.5	87.0		86.1	87.1				94.2
34				94.3					86.8		85.6	87.0				94.1
35				94.1												

Site inaccessible due to high flows.

Table 3.2-3c. TFI Vertical Profile Results for 2015 – Upstream of Turners Falls Dam & Boat Barrier (Site 7)
Dissolved Oxygen Percent Saturation

Depth (m)	3-Apr	30-Apr	14-May	29-May	10-Jun	25-Jun	10-Jul	24-Jul	6-Aug	18-Aug	3-Sep	18-Sep	9-Oct	23-Oct	4-Nov	11-Nov
0	Site inaccessible due to ice.	Site inaccessible due to high flows.	98.5	98.6	98.1	Site inaccessible due to high flows.	98.0	96.9	94.3	103.2	94.0	95.9	96.0	93.9	96.4	96.2
1			98.0	97.4	97.4		97.9	96.6	94.3	103.3	94.0	95.0	96.3	93.7	96.0	96.0
2			97.9	99.2	97.2		97.7	96.2	94.0	102.3	90.8	94.7	96.2	93.6	95.7	95.8
3			97.7	99.1	96.9		97.4	95.9	93.7	99.3	90.1	94.6	95.8	93.5	95.4	95.5
4			97.6	98.7	96.6		97.2	95.9	93.5	97.5	89.9	94.4	95.4	93.5	95.2	95.2
5			97.4	98.5	96.4		96.8	95.1	93.4	96.4	88.5	94.2	94.7	93.4	94.9	95.0
6			97.3	98.2	96.4		96.4	94.9	93.3	96.1	88.2	94.0	94.3	93.3	94.8	94.9
7			97.2	97.8	96.3		96.1	94.7	93.1	95.8	87.8	92.0	94.1	93.4	94.4	94.7
8			97.0	97.5	96.0		95.9	94.6	92.8	95.6	87.5	91.2	94.2	93.3	94.1	94.6
9			97.0	97.3	96.0		95.7	94.4	92.5	95.6	86.4	90.9	93.8	93.1	93.8	94.5
10			96.8	97.0	95.8		95.5	94.2	92.4	95.5	84.8	90.7	93.6	92.9	93.6	94.2
11			96.6	97.0	95.6		94.9	94.0	92.3	94.7	85.0	91.1	93.4	92.7	93.4	93.8
12			96.5	96.7	95.4		94.2	93.9	92.1	94.5	84.6	91.4	93.3	92.5	93.2	93.7
13			96.5	96.4	95.2		94.1	93.7	91.9	94.1	83.2	90.5	93.1		93.1	93.5
14			96.3	96.1	95.0											
15			96.3	95.9	94.8											
16			96.3	95.7												
17			96.1													
18			96.0													

Table 3.2-4: Difference between the Surface and Bottom Measurements in Vertical Profiles

Location	Δ (Surface – Bottom)								
	Temperature (°C)			DO (mg/L)			DO (%sat)		
	Min	Max	Average	Min	Max	Average	Min	Max	Average
Site 2 – Deep area upstream of Northfield Mountain	0.0	0.3	0.1	0.2	0.4	0.3	1.4	3.9	2.9
Site 6 – Deepest area of TFI	0.1	0.4	0.2	0.3	0.6	0.5	2.6	5.8	4.8
Site 7 – Upstream of Turners Falls Dam & Boat Barrier	0.0	0.9	0.3	0.1	0.8	0.3	1.4	10.8	4.1

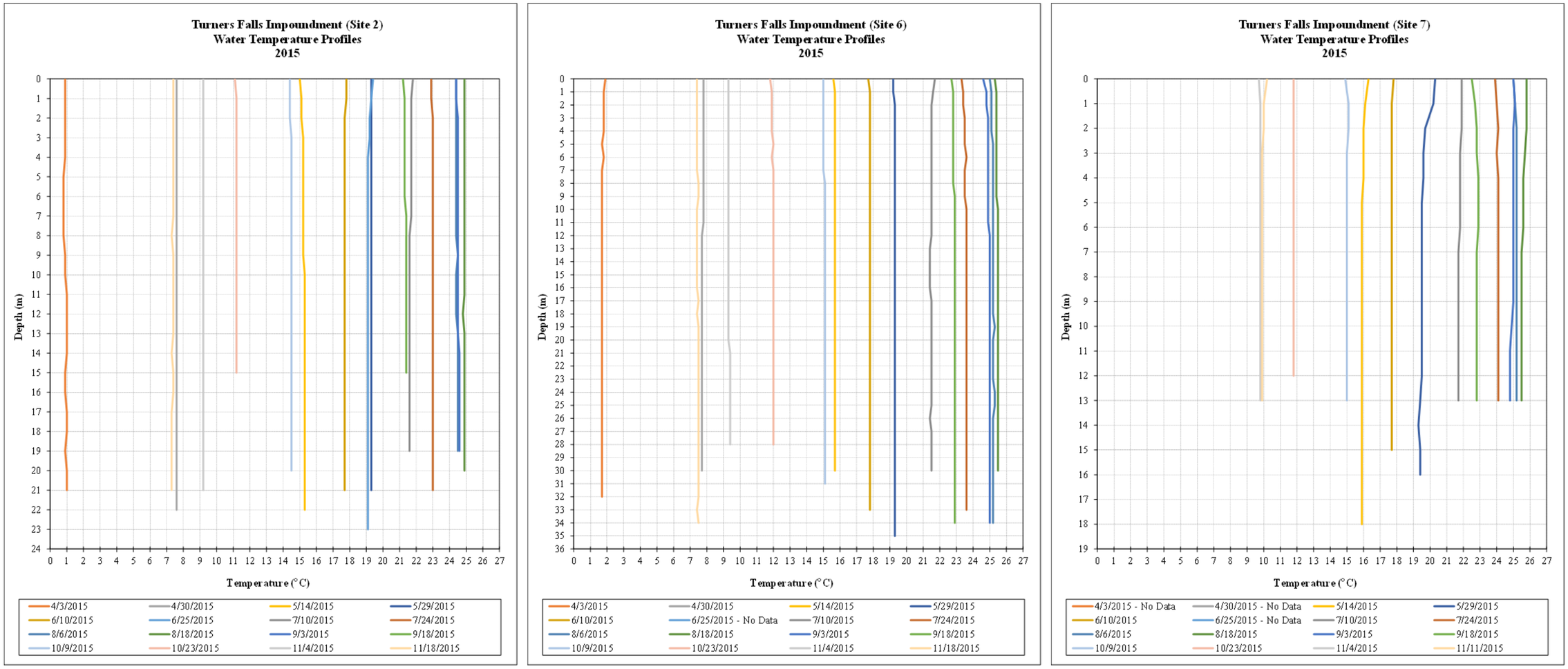


Figure 3.2-1: Vertical Profiles of Water Temperature Collected in the Turners Falls Impoundment, April – November 2015.

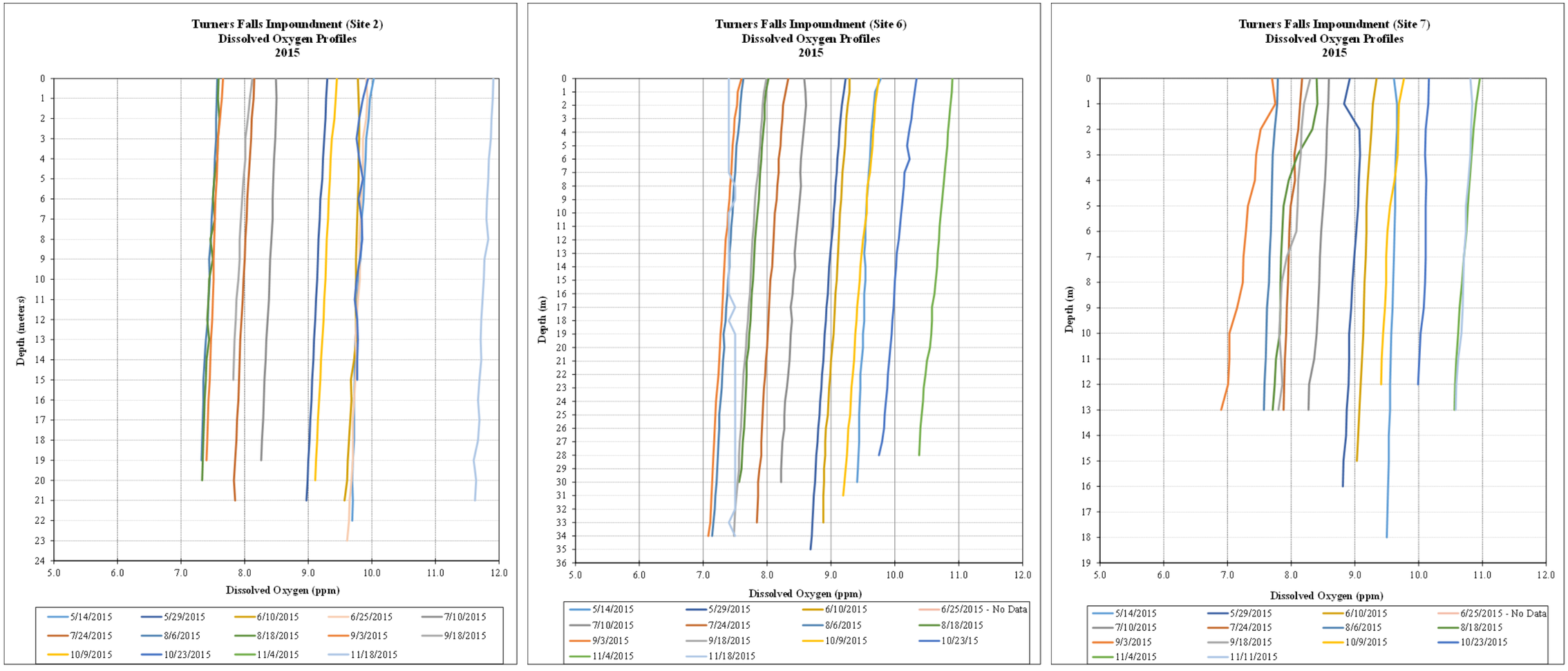


Figure 3.2-2: Vertical Profiles of DO (mg/L) Collected in the Turners Falls Impoundment, April – November 2015

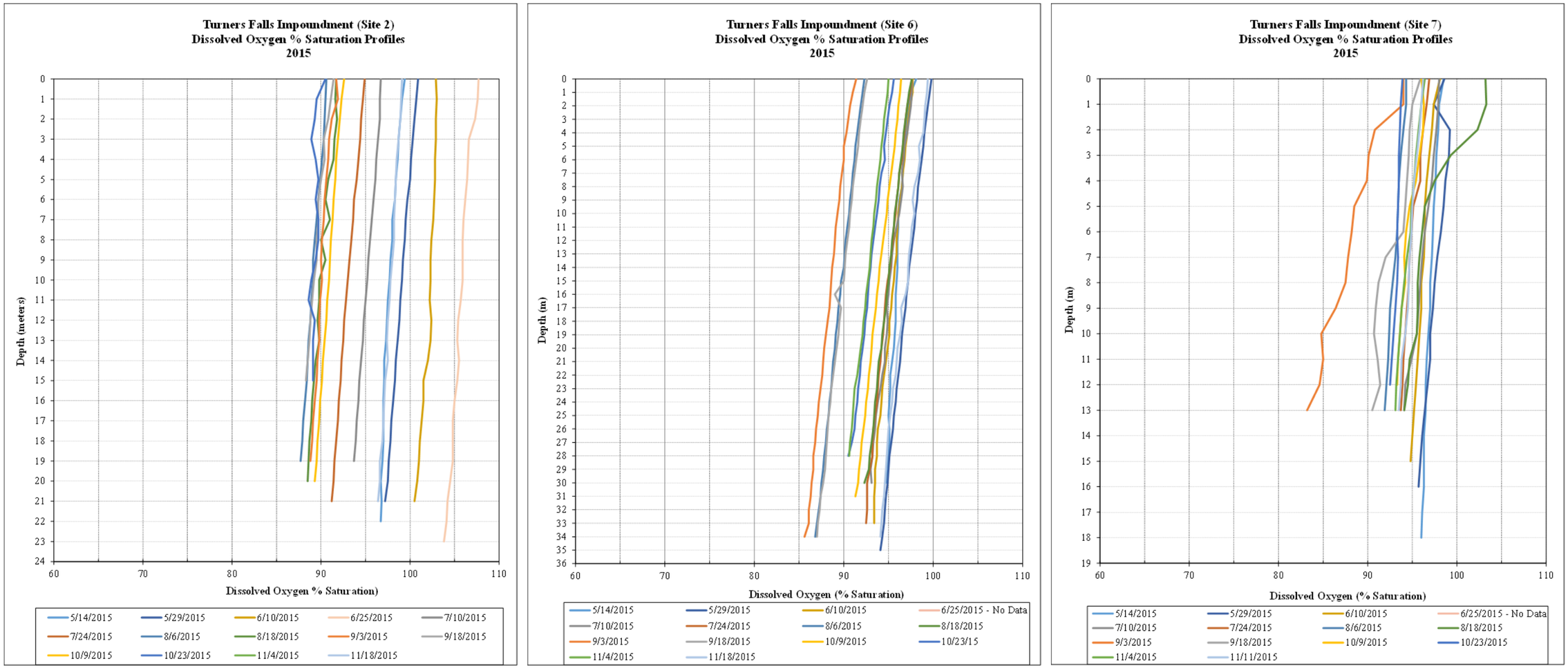


Figure 3.2-3: Vertical Profiles of DO (percent saturation) Collected in the Turners Falls Impoundment, April – November 2015.

3.3 Continuous Monitoring

The continuous DO and water temperature data collected from the 16 data loggers for the 2015 sampling period are presented in this section of the report. Refer to Table 2.1-1 for the deployment and retrieval dates for each data logger. Note that at the beginning of the monitoring period in April (and May for Site 7), many of the monitoring sites were deployed on different dates, as detailed in Section 2.7.1 of this report. The reader should take this into account when comparing summary statistics across sites throughout this report.

Table 3.3-1 provides the overall minimum, maximum and average DO and temperature values observed during the study period at each continuous monitoring location. Additionally, while various charts and tables are presented in the main body of this report, due to the amount of data and number of monitoring sites monthly plots were developed for the complete monitoring periods and are contained in appendices to the this report. The outline for the charts in the appendices is summarized below.

Appendix E contains monthly plots of DO concentration versus flow and Appendix F contains monthly plots of DO percent saturation versus flow. Both sets of plots present data series grouped by monitoring sites, as follows:

- Sites 1-7: TFI- includes comparison of DO versus Vernon discharge and Northfield Mountain pumping and generation flows.
- Sites 8-11: Bypass reach, power canal and below Cabot- includes comparison of DO versus Turners Falls Dam spill, Station No. 1 discharge and Cabot Station discharge.

Appendix G contains monthly plots of temperature versus flow, with sites grouped similar to the DO plots above. An additional set of temperature plots is included showing data from:

- Sites 11-18: Below Cabot - includes comparison of temperature versus Cabot Station discharge and Montague USGS Gage flows (captures sum of Deerfield River flows, bypass reach flows and Cabot Station discharge).

3.3.1 Overview of Dissolved Oxygen

DO concentrations from within the TFI, the bypass reach, the power canal, and below Cabot Station (i.e., Site 1 through Site 11) remained above the MA water quality standard of 5.0 mg/L minimum (Table 3.3-1). The average DO concentrations observed for Sites 1 through 7 in the TFI were between 8.5 mg/L and 8.8 mg/L (approx. 97.1% and 99.5% saturation). Sites 8 and 9 in the bypass reach had slightly higher average DO values compared to other sites. Average DO values at Site 10 (Power Canal) and Site 11 (Below Cabot Station) were not as high as the bypass reach sites. The maximum observed DO concentration was 16.1 mg/L (and 181.3% saturation) at Site 8 in June. The minimum observed DO concentration was 5.8 mg/L (and 71.1% saturation) at Site 11 below Cabot Station.

Figures 3.3.1-1 and 3.3.1-2 shows the average, minimum and maximum monthly DO concentrations and percent saturation values, respectively, for mid-May through September 2015. All sites had the highest monthly average DO concentrations in the cool, wet month of June; the lowest monthly average DO concentrations were recorded in the warm, low flow months of August and September. Monthly average DO results were generally similar among TFI Sites 1 through 7. Site 8, in the bypass reach, had the highest average DO each month. Site 11, downstream of Cabot Station had concentrations similar those of the bypass reach and those of the power canal. A summary of monthly data results is included in Table 3.3.1-1.

Higher concentrations of DO were most commonly observed in the bypass reach downstream of Turners Falls Dam. Figure 3.3.1-2 shows the average, minimum and maximum monthly DO saturation concentrations. A black dotted line on the figure indicate 100% DO saturation.

3.3.2 Overview of Water Temperature

The water temperatures observed at each location (i.e., Sites 1 to 18) remained below the MA water quality standard of a 28.3°C maximum for Class B warm water fisheries. The maximum temperature observed across all sites ranged from 26.4°C to 28.1°C. A series of bar charts are presented to depict the monthly average, maximum and minimum water temperature for the sites in the TFI (Figure 3.3.2-1), bypass reach/power canal (Figure 3.3.2-2) and below Cabot Station (Figure 3.3.2-3) for April through November 15, 2015. Error bars display the observed maximum and minimum temperatures for each location. The black dotted line represents the MA WQ standard of 28.3°C. The supporting monthly data are included in Table 3.3.2-1.

Monthly average temperatures were very similar among all locations and increased approximately 10°C for most sites between April and May (from approximately 5°C to 15°C). August was the warmest month for all locations with an average water temperature of approximately 25°C. July and September were the second warmest months with average water temperatures of approximately 23°C. Monthly average water temperatures decreased by approximately 10°C between September and October (from approximately 23°C to 13°C).

Table 3.3-1. Minimum, Maximum and Average DO and Temperature for each Continuous Water Quality Monitoring Location

Sampling Location	Approximate Depths		Water Temperature (°C)			Dissolved Oxygen (mg/L)			Dissolved Oxygen (%sat)		
	Logger (ft)	Water (ft)	Min	Max	Avg.	Min	Max	Avg.	Min	Max	Avg.
Site 1 - Inflow	6	23	1.0	26.9	16.6	6.3	10.9	8.8	76.6	117.3	99.5
Site 3 - Above Northfield Mountain	6	26	0.7	27.1	17.1	7.0	10.9	8.7	83.3	117.5	98.9
Site 4 - Northfield Mountain Tailrace	5	20	0.6	26.5	17.2	6.9	11.0	8.7	84.1	116.9	98.7
Site 5 - Below Northfield Mountain	10	40	0.7	26.4	17.2	6.6	10.7	8.5	81.5	112.2	97.1
Site 7 - Above Turners Falls boat barrier	12	50	9.2	26.6	19.8	6.4	10.8	8.7	79.0	114.2	98.7
Site 8 - Upstream of Station No.1	bottom	3	0.9	27.4	17.0	6.1	16.1	9.4	71.9	181.3	106.9
Site 9 - Rawson Island	bottom	2	1.0	27.4	17.0	6.9	11.6	8.9	78.9	128.5	101.0
Site 10 - Power Canal	10	20	0.9	26.7	17.3	6.4	10.9	8.6	78.7	111.2	98.7
Site 11 - Below Cabot Station	5	22	2.2	26.9	17.8	5.8	11.2	8.8	71.1	117.0	100.3
Site 12 - Downstream of Deerfield River	bottom	7	7.1	27.1	19.0	Temperature only at Sites 12-18					
Site 13 - Third Island	bottom	6	2.3	27.1	17.5						
Site 14 - Second Island	bottom	5	2.4	27.0	17.9						
Site 15 - Submerged Shallow Bar	bottom	8	2.4	27.7	17.8						
Site 16 - Submerged Shallow Bar	bottom	6	2.8	28.1	17.9						
Site 17 - Elwell Island	bottom	9	2.5	27.9	18.1						
Site 18 - Mitch's Island	bottom	6	2.5	27.5	18.1						

Note: water depths are those at time of deployment; depth at each location can vary across seasons.

Table 3.3.1-1. Monthly 2015 Dissolved Oxygen Concentration and Percent Saturation Results for Continuous Monitoring Sites

	Site 1		Site 3		Site 4		Site 5		Site 7		Site 8		Site 9		Site 10		Site 11	
	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%
May																		
Ave	9.68	101.1	10.09	105.1	9.90	103.1	9.73	101.3	9.78	102.0	10.53	109.9	10.19	106.4	9.87	103.1	9.89	103.4
Min	8.49	94.3	8.91	97.8	8.79	96.0	8.64	95.3	8.94	97.5	8.99	100.5	8.93	97.50	9.08	96.3	8.89	95.9
Max	10.31	109.9	10.94	117.5	10.79	115.0	10.41	111.3	10.53	109.8	11.84	119.1	11.57	117.70	10.36	108.8	11.16	114.9
June																		
Ave	9.53	102.4	9.48	101.5	9.56	102.9	9.52	102.4	9.64	103.9	10.38	112.0	9.64	104.0	9.54	103.0	9.86	106.5
Min	8.68	94.4	8.75	95.6	8.56	93.8	8.59	94.0	8.72	95.2	6.54	71.9	8.18	89.1	8.71	95.8	8.92	97.4
Max	10.85	110.2	10.92	110.9	10.97	111.8	10.73	109.6	10.82	112.0	16.13	181.3	11.42	115.8	10.88	111.2	11.15	114.2
July																		
Ave	8.57	99.8	8.53	99.2	8.70	101.3	8.58	99.7	8.71	101.5	9.41	109.3	8.41	98.0	8.67	101.2	8.75	102.1
Min	7.42	87.1	7.79	91.6	7.22	87.6	7.23	87.4	7.22	87.4	7.81	92.1	6.91	78.90	7.84	93.5	5.81	71.1
Max	9.86	111.1	9.55	111.0	10.04	116.9	9.85	112.2	10.06	114.2	15.32	168.9	11.41	128.50	9.57	108.8	10.52	117.0
August																		
Ave	7.93	96.2	7.96	97.0	7.82	95.5	7.67	93.6	7.84	95.8	8.53	103.4	8.31	101.2	7.87	96.3	7.94	97.2
Min	6.26	76.6	6.95	85.0	6.94	84.1	6.64	81.5	6.79	82.0	6.06	74.8	7.54	91.1	6.38	78.7	5.95	73.1
Max	9.50	117.2	8.80	110.0	8.89	110.5	8.43	104.0	8.65	107.2	9.56	118.7	9.45	116.1	8.56	105.3	8.56	106.7
September																		
Ave	8.67	98.2	8.13	94.6	7.90	92.5	7.72	90.2	7.85	91.8	8.78	101.3	8.40	97.92	7.82	91.68	8.01	93.8
Min	7.24	86.9	7.07	83.3	7.03	84.7	6.95	83.3	6.42	79.0	7.51	89.5	7.42	90.40	6.79	83.60	7.23	86.8
Max	10.54	117.3	9.49	105.2	9.36	104.7	9.26	102.0	9.25	104.5	10.44	115.7	10.54	117.20	8.84	99.30	9.50	106.1

Table 3.3.2-1. Monthly Temperature Results for Continuous Data Loggers (April – November 15, 2015)

	Site 1	Site 3	Site 4	Site 5	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12	Site 13	Site 14	Site 15	Site 16	Site 17	Site 18
April																
Ave	4.66	4.28	4.24	4.30	NO DATA	4.51	4.46	4.23	5.45	NO DATA	5.49	5.49	5.52	5.90	5.73	5.73
Min	0.99	0.66	0.63	0.66		0.89	1.00	0.85	2.18		2.30	2.41	2.41	2.84	2.52	2.52
Max	9.34	8.42	8.32	8.39		8.48	8.48	8.44	8.39		8.68	8.68	8.88	9.28	8.98	8.88
May																
Ave	16.00	15.55	15.46	15.55	17.37	15.74	15.73	15.64	15.74	15.76	15.90	15.51	15.99	16.29	16.33	16.36
Min	8.49	8.07	6.64	7.80	15.32	8.28	8.28	8.12	8.27	8.28	8.28	8.28	8.38	8.68	8.38	8.38
Max	21.96	21.62	21.74	21.54	21.22	21.98	21.64	21.22	21.56	21.95	22.24	22.24	22.91	22.72	22.53	22.81
June																
Ave	18.69	18.53	18.79	18.73	18.84	18.90	18.91	18.90	18.93	18.91	19.02	19.82	19.03	19.18	19.31	19.36
Min	14.60	14.44	14.64	14.62	15.18	15.52	15.66	15.30	15.66	15.66	15.86	18.05	15.95	15.95	15.86	15.86
Max	21.12	21.12	21.14	21.18	21.10	21.20	21.50	21.16	21.26	21.28	21.28	21.41	21.47	21.66	21.95	22.05
July																
Ave	22.67	22.60	22.67	22.70	22.75	22.65	22.67	22.80	22.82	22.57	22.63	22.64	22.69	22.71	23.02	23.09
Min	17.60	17.40	17.52	17.50	17.60	17.76	17.74	17.68	17.80	17.76	17.95	18.14	18.24	18.24	18.24	18.24
Max	26.10	26.30	25.92	25.64	25.70	26.74	26.62	25.48	25.64	26.10	26.29	26.20	26.59	26.39	26.49	26.29
August																
Ave	24.93	25.11	25.23	25.23	25.31	24.82	25.07	25.40	25.33	25.09	25.23	25.21	25.26	25.19	25.58	25.54
Min	23.10	23.76	23.86	23.92	24.32	21.14	21.58	24.42	23.90	23.10	23.00	23.58	23.39	23.00	23.58	23.87
Max	26.90	27.08	26.50	26.44	26.62	27.40	27.44	26.70	26.86	27.08	27.08	26.98	27.57	28.06	27.86	27.47
September																
Ave	21.48	23.01	23.27	23.25	23.29	22.52	23.09	23.39	23.24	22.91	22.83	22.97	22.97	22.89	23.18	23.25
Min	18.30	19.20	19.48	19.48	19.56	18.22	18.66	19.70	19.68	19.19	19.00	19.19	18.90	18.81	19.09	19.57
Max	26.14	26.26	25.94	25.74	25.90	26.78	26.44	26.18	26.66	26.59	26.59	26.49	27.67	27.86	27.57	26.98
October																
Ave	12.88	13.10	13.39	13.33	13.44	13.31	13.30	13.04	13.42	13.28	13.19	13.27	13.30	13.25	13.50	13.53
Min	8.72	9.29	9.24	9.26	9.34	8.68	8.88	9.36	9.36	9.28	9.28	9.28	9.18	9.37	9.37	9.67
Max	18.30	19.16	19.42	19.46	19.52	19.56	19.40	19.66	19.66	19.28	19.38	19.47	19.47	19.19	19.28	19.57
Through November 15																
Average	9.27	9.51	9.60	9.56	9.86	9.57	9.60	9.65	9.66	9.61	9.59	9.59	9.64	9.68	9.78	9.82
Min	6.05	7.75	7.90	7.80	9.16	7.38	7.48	7.96	7.92	7.78	7.78	7.88	7.88	7.88	7.88	7.78
Max	11.66	10.81	10.76	10.74	10.81	11.24	11.14	10.60	11.05	11.04	11.43	11.24	11.33	11.24	11.43	11.72
SUMMARY																
Average	16.64	17.10	17.23	17.23	19.77	16.99	17.03	17.25	17.85	18.96	17.48	17.85	17.82	17.91	18.10	18.13
Min	0.99	0.66	0.63	0.66	9.16	0.89	1.00	0.85	2.18	7.78	2.30	2.41	2.41	2.84	2.52	2.52
Max	26.90	27.08	26.50	26.44	26.62	27.40	27.44	26.70	26.86	27.08	27.08	26.98	27.67	28.06	27.86	27.47

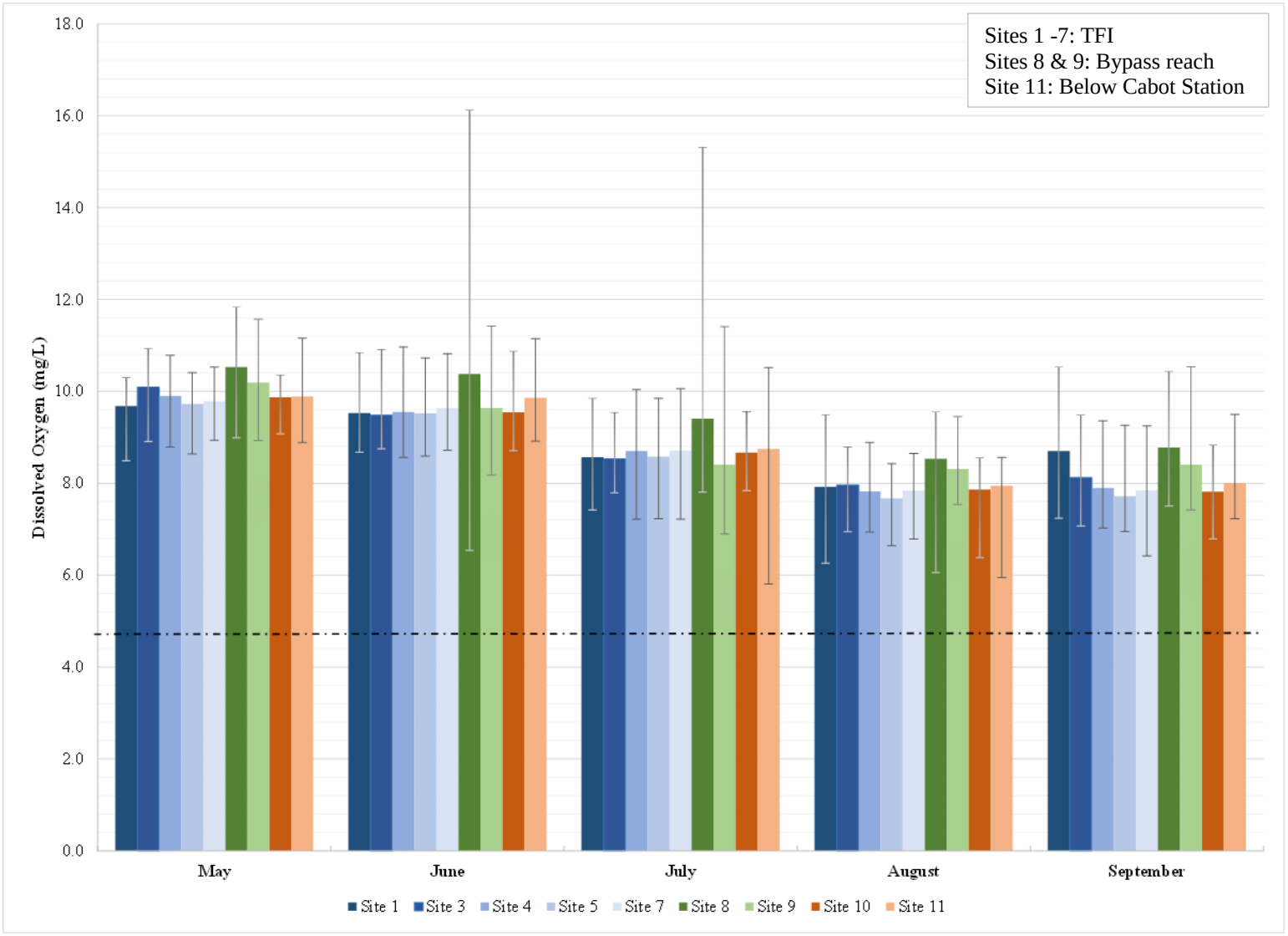


Figure 3.3.1-1: Monthly Average, Minimum and Maximum DO Concentrations, Mid-May – September, 2015

Minimum and maximum DO concentrations are displayed as plus and minus error bars. The black dotted line represents the MA water quality standard minimum of 5 mg/L DO for Class B warm water fisheries.

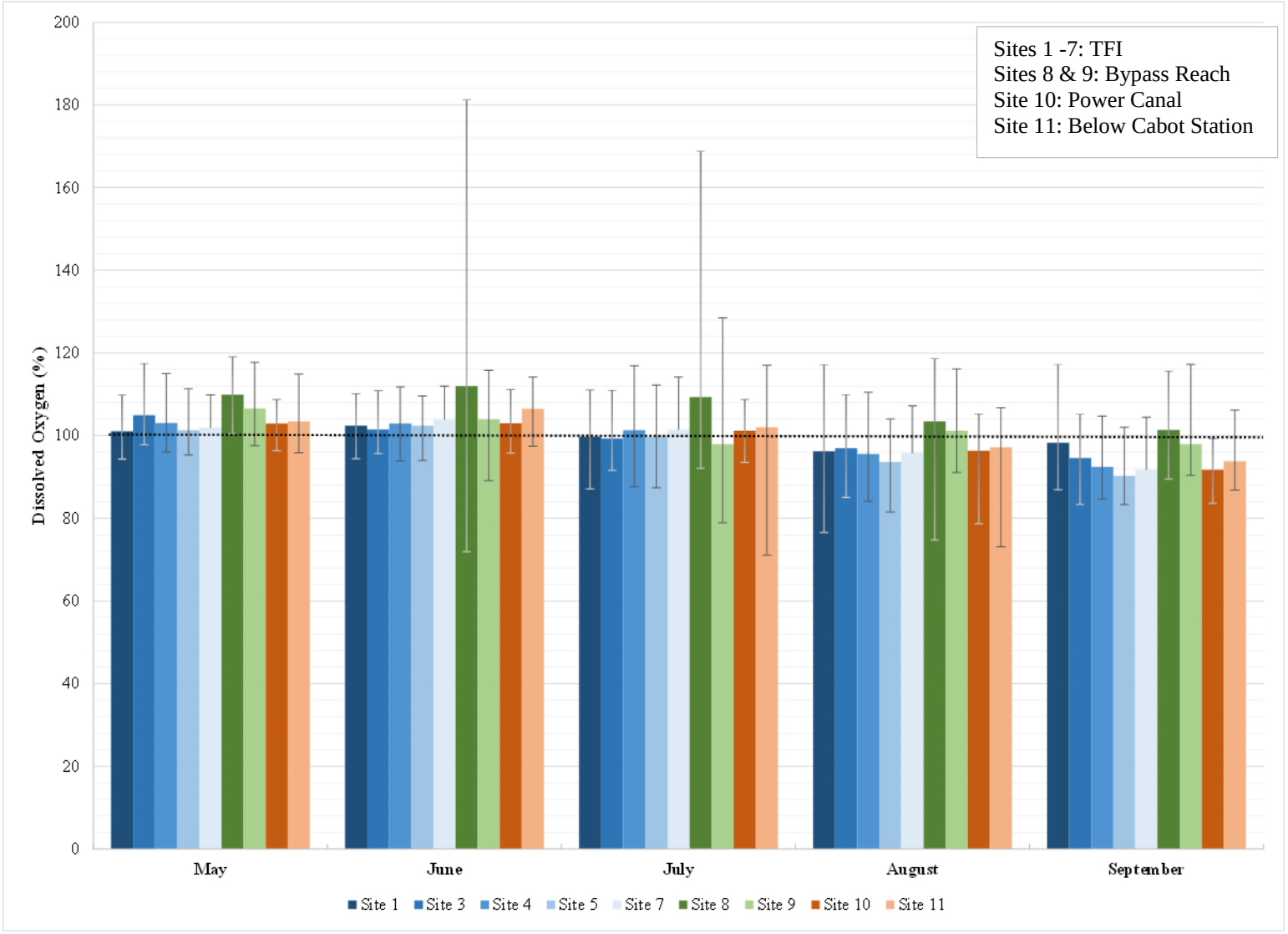


Figure 3.3.1-2: Monthly Average, Minimum and Maximum Percent DO Saturation, Mid-May – September, 2015

Maximum and minimum DO percent saturation values are displayed as error bars. The black dotted line represents 100% DO saturation

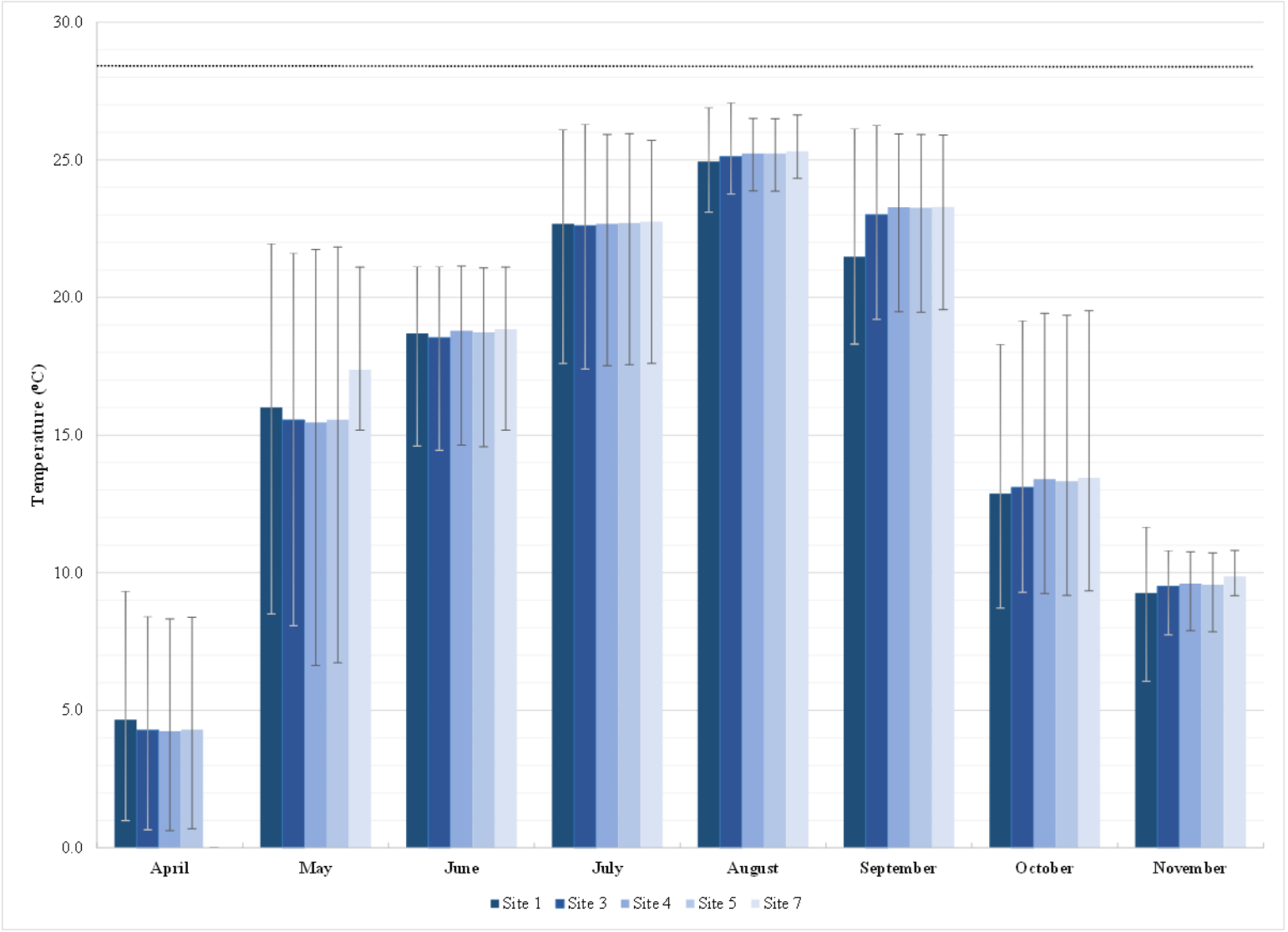


Figure 3.3.2-1: Monthly Average, Minimum and Maximum Temperatures for TFI Locations

Minimum and maximum temperatures are displayed as plus and minus error bars. The black dotted line represents the MA WQ standard of 28.3°C.

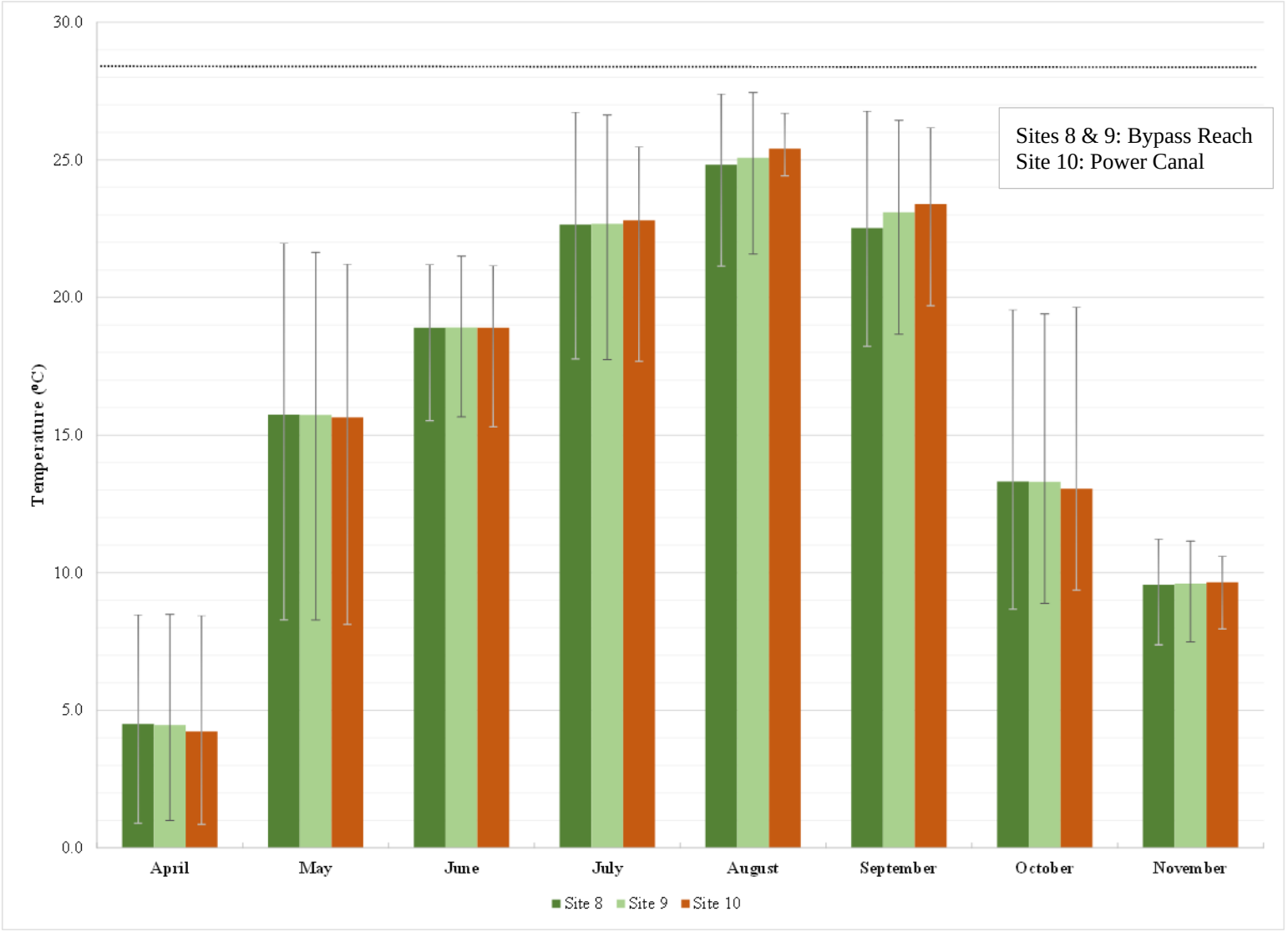


Figure 3.3.2-2: Monthly Average, Minimum and Maximum Temperatures for the Bypass Reach and Power Canal Locations

Minimum and maximum temperatures are displayed as plus and minus error bars. The black dotted line represents the MA WQ standard of 28.3°C.

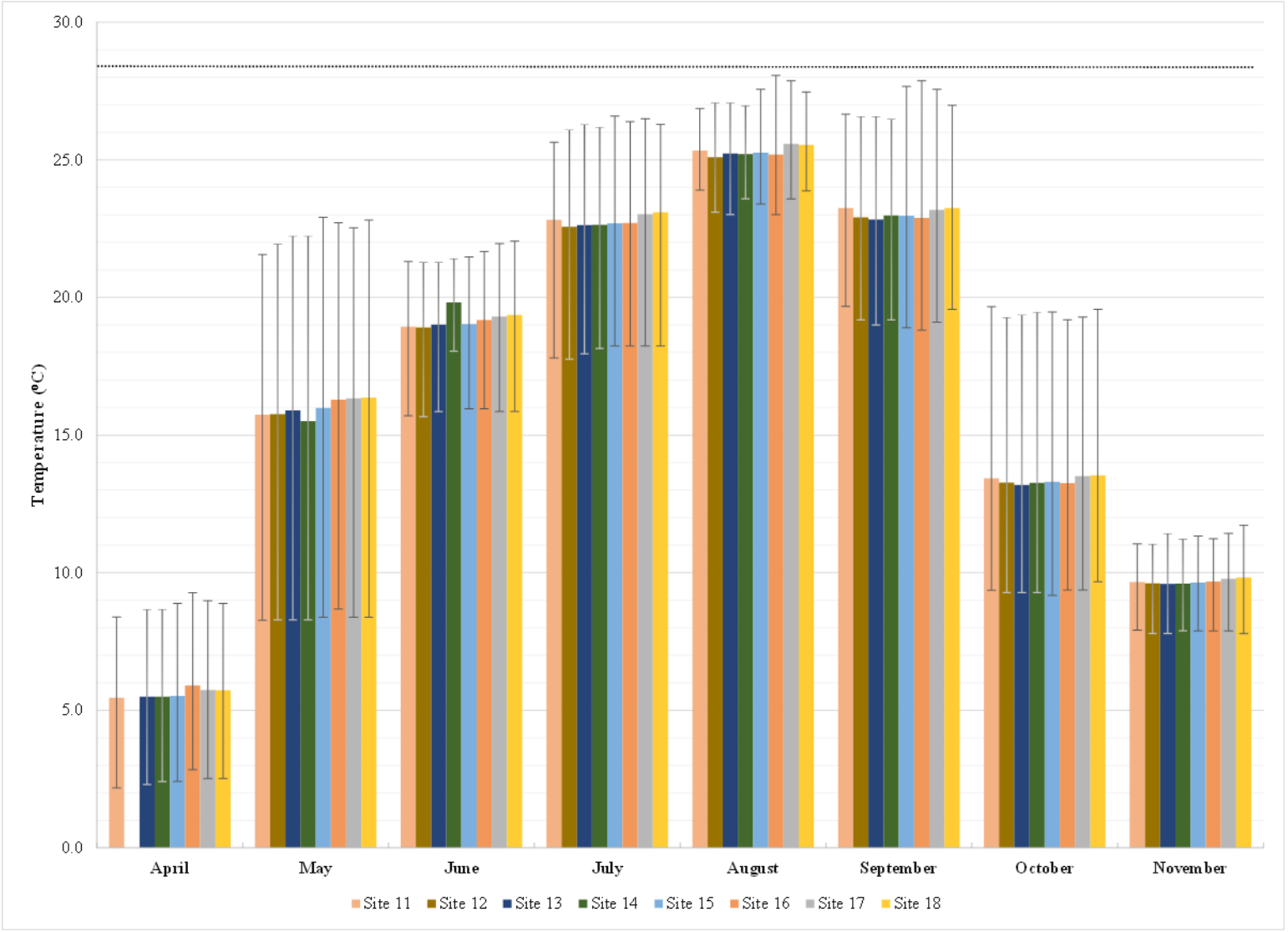


Figure 3.3.2-3: Monthly Average, Minimum and Maximum Temperatures for Locations below Cabot Station

Minimum and maximum temperatures are displayed as plus and minus error bars. The black dotted line represents the MA WQ standard of 28.3°C.

3.4 Project-Related Trends

3.4.1 Turners Falls Impoundment

The main inflow to the TFI is governed by TransCanada's Vernon Hydroelectric Project, which operates as a peaking hydroelectric facility with a maximum hydraulic capacity of 17,130 cfs. The drainage areas at the Vernon Dam and Turners Falls Dam are 6,266 and 7,163 square miles (mi^2), respectively, a difference of 897 mi^2. The remainder of the drainage area is attributable to two main tributaries- the Ashuelot River (420 mi^2) and Millers River (372 mi^2) that drain into the TFI (combined drainage area of 792 mi^2).

The Northfield Mountain Project is located on the TFI and generally pumps water up to its Upper Reservoir at night and generates during the day when there is increased demand for power. Examples of diurnal DO and temperature patterns at the water quality sites in the TFI under various inflow and Project operations scenarios are presented in this section.

May 1-7, 2015 was a period in the spring where Vernon flows were relatively stable and the Northfield Mountain Project was idle (during May 2-3). Typical diurnal patterns of daily warming and cooling were apparent and more pronounced at Site 1 during this period (Figure 3.4.1-1). Within this period, when Northfield Mountain generation is occurring, water temperatures and DO levels at Site 4 were influenced by discharge from Northfield Mountain. In this case, water temperatures are slightly cooler by approximately 1.5 °C. Note that Site 7 (TFI boat barrier) is not reflected in this figure because the Site 7 data logger was not deployed until May 14.

May 23 through May 27 reflects another period when inflows were very low and Northfield Mountain was operating intermittently. During this time, water temperatures showed a typical daily pattern when Northfield Mountain was idle between the morning of May 24 to the afternoon of May 25 (Figure 3.4.1-2a). When Northfield Mountain was generating (May 26-27), water temperatures at Site 4 and 5 were again slightly cooler compared to upstream locations. May 2015 was a very dry and warm month and during the period, the Northfield Mountain upper reservoir was slightly cooler compared to the Connecticut River. Figures 3.4.1-2b and 3.4.1-2c shows DO concentration and percent saturation values during May 23 through May 27. When Northfield Mountain was generating, DO values could vary at Site 4 in the vicinity of the tailrace by approximately ±1.0 mg/L. Similar, but less pronounced patterns were observed at Site 5, downstream of the Northfield Mountain tailrace.

Similar trends were observed during a warmer period in late August-early September (Figures 3.4.1-1a through 3.4.1-3c). During this period, Vernon generation ranged from approximately 1,600 to 12,000 cfs and Northfield Mountain was pumping and generating on a daily cycle. DO and temperature exhibited a typical diurnal pattern at Site 1 whether Vernon was generating or at minimum flow. Water temperatures at other sites were more uniform throughout the day, even when Northfield Mountain was generating. During this period, the temperature of the Northfield Mountain upper reservoir was consistent with the main Connecticut River. Daily DO fluctuations were less pronounced at Sites 3-7, ranging from 8.1 to 6.8 mg/L, compared to Site 1 during this period.

When inflows to the TFI increased in response to precipitation events during warm months, water temperatures cooled and diurnal fluctuations diminished. An example is provided in Figure 3.4.1-4. Precipitation between September 30 and October 1 resulted in approximately 4 inches of rain; inflows from Vernon consequently increased to approximately 30,000 cfs and water temperatures throughout the TFI cooled. During this period, the Northfield Mountain upper reservoir remained warmer than the Connecticut River resulting in water approximately 2 °C warmer at the tailrace (Site 4) and downstream of the tailrace (Site 5) during Northfield Mountain generation on October 4 and 5.

3.4.2 Bypass Reach

Flow in the bypass reach is influenced by Turners Falls Dam spill, spillway fishway and attraction flow releases, the Fall River (a tributary discharging into the upper portion of the bypass), Station No. 1 leakage and discharge, and other canal water users. Cabot Station discharges can backwater into the lower portion of the bypass reach below Rock Dam. In this section of the report, DO and water temperature conditions in the bypass reach were examined under different operating scenarios: 1) under minimum flow of 120 cfs; 2) during periods when Station No. 1 was generating, and 3) during periods of spill at Turners Falls Dam. Monthly water quality charts in relation to the Turners Falls Dam spill and Station No. 1 discharge are included in Appendices E, F and G.

Water temperature and DO at the two water quality sites in the bypass reach (Sites 8 and 9) were very similar to one another under minimum flow conditions. Figures 3.4.2-1a, 3.4.2-1b and 3.4.2-1c show the typical diurnal pattern of DO (mg/L and percent) and temperature, respectively, prevalent at both bypass reach sites while Turners Falls Dam is not spilling and Station No. 1 is not generating. At both sites, daily temperature and DO levels would rise during the day and fall during the night in response to ambient warming/cooling and biological activity, respectively. The bypass reach remains well-oxygenated under minimum flow conditions.

Figures 3.4.2-2a, 3.4.2-2b and 3.4.2-2c show water quality conditions in the bypass reach during May 15-June 14, 2015. Controlled spill and Station No. 1 releases were being provided during this period in support of other relicensing studies. Water temperatures during this period were consistent with Site 7 in the TFI. The period during June 1-3 experienced a precipitation event which resulted in spill flow of approximately 17,000 cfs. This event cooled water temperatures throughout the bypass reach and at Site 7. DO was generally 1-2 mg/L higher in the bypass reach compared to Site 7 in the TFI during periods of spill as shown in Figures 3.4.2-2b and 3.4.2-2c. Note that during this period, DO percent saturation in the bypass reach generally remained between 100-120 percent saturation.

There was a period during late June-early July when DO levels in the bypass reach, at Site 8 in particular, were recorded in excess of 150 percent saturation (maximum value = 181%). Again, during this period, controlled spill and Station No. 1 releases were being provided in support of other relicensing studies. Figure 3.4.2-3 shows the daily fluctuation of DO %sat at Sites 8 and 9 in the bypass reach in relation to Turners Falls Dam spill and Station No. 1 generation. Site 7 DO is also shown for comparison. Further downstream, DO levels dissipate at Site 9 near Rawson Island. DO percent saturation values in the TFI at Site 7 ranged from 83.2 to 103.2, therefore the higher percent saturation values observed in the bypass reach at Site 8 are likely due to hydraulic and biological processes occurring downstream of the Turners Falls Dam.

Turners Falls Dam spillage is likely to be the major contributing factor to supersaturation in the bypass reach because there were multiple instances in which high DO concentrations occurred as the Turners Falls Dam was spilling considerable flow. However, the maximum daily peaks in DO percent saturation are still high even during a period of constant spill rates (e.g., July 7-9, 2015). This suggests that biological factors may be involved in addition to the aeration provided as water is spilled over the dam. DO supersaturation can be caused by multiple factors, including temperature, photosynthesis, turbulent waters and rapid aeration from dam spillage. The bypass reach has very rocky terrain and steep channel gradients, which, in combination with fast-moving waters, will naturally create turbulence (such as riffles), that oxygenate the water. The bypass reach also has slick, algae-covered rocks in places; algal photosynthesis could lead to higher DO levels as well.

In late summer, from August 22 through September 26, 2015, Station No. 1 was generating consistently without spill in the bypass reach. Figure 3.4.2-4a shows the water temperatures and Figure 3.4.2-4b shows the DO concentrations during this period. Water temperatures at Site 8, upstream of Station No. 1 discharge, are periodically cooler compared to the other water quality sites in the bypass reach (Site 9 near Rawson Island) and at Site 7 in the TFI. The reasons for this are unclear, however, there may have been an influence

from other flow inputs into the bypass reach such as from the Fall River or canal water users during this period. DO concentrations are slightly higher or very similar at Site 8 compared to Site 9 during this period. Note that on August 23, during start-up of Station No. 1, a short-term decrease in DO was evident; DO levels rebounded within a few hours of Station No. 1 coming on-line and remained above 6.0 mg/L during the entire monitoring period. Once Station No. 1 is running consistently, DO percent saturation levels generally ranged between 90-115% (see Figure 3.4.2-4c).

Turners Falls Dam spillage and Station No. 1 operation both seem to have an effect on DO and temperature in the bypass reach; more so at Site 8 than at Site 9. Higher spill at Turners Falls Dam generally correlated with higher DO at Site 8. Both controlled (i.e., operational) and uncontrolled (i.e., natural from precipitation) spill would often cause the bypass reach to become supersaturated. Regardless, MA WQ standards for DO and temperature were met at all times at the two locations within the bypass reach.

3.4.3 Power Canal

Flow into the power canal from the TFI is controlled by the gatehouse. Station No. 1 draws water out of the power canal while it is operating and Cabot Station releases water from the power canal while it is operating. Water temperature in the power canal is fairly constant throughout the day, despite changes in canal flow and tracks similar to water temperatures measured at Site 7 in the TFI (Figure 3.4.3-1a). Daily temperature ranges are slightly higher when flow in the power canal is relatively low (e.g., Sept 6-7). DO concentration and percent saturation showed similar trends compared to Site 7 in TFI (Figure 3.4.3-1b and Figure 3.4.3-1c).

3.4.4 Downstream of Cabot Station - Site 11 (DO and Temperature)

Water quality Site 11 was located below the bridge downstream of Cabot Station, approximately 500 feet upstream from the mouth of the Deerfield River. Cabot Station and bypass reach flows will influence this location, as will the Deerfield River under higher flows. Site 11 was the most downstream DO monitoring location in this study. Data from Site 11 were therefore plotted in relation to Site 10 (power canal) and Site 9 (bypass reach near Rawson Island) as well as against discharge from Turners Falls Dam, Station No. 1, Cabot Station and the Montague USGS gage. Appendix E through G contain the monthly water quality plots.

Figures 3.4.4-1a, 3.4.4-1b, and 3.4.4-1c display DO and water temperature during a high temperature and low flow situation. Data from Site 11 tracks closely to conditions in the power canal while Cabot Station is generating and closely to Site 9 near Rawson Island when Cabot Station is off-line. The diurnal range of DO concentration at Site 11 is typically less than 0.5 mg/L. Because the Turners Falls Impoundment stays well-mixed, the water that passes through the power canal and Cabot Station is well-oxygenated and of similar temperature compared to other locations.

Figures 3.4.4-2a, 3.4.4-2b, and 3.4.4-2c show DO and water temperature at Site 11 from July 27 through August 7, 2015. DO levels starting on July 29 through August 3 display an anomalous trend in that Site 11 has temperatures similar to surrounding sites, but lower DO. The minimum DO recorded during this period was 5.81 mg/L (71.1 %sat). Typical diurnal patterns are observed at surrounding water quality monitoring sites and Cabot Station is generating to various degrees during this period. The low DO during this period is unexplained and may be due to instrument fouling, but this could not be confirmed as DO values come back in-line with power canal values on August 3, all during the same biweekly monitoring period.

3.4.5 Connecticut River Downstream of Cabot Station – Temperature and Temperature Rate of Change

Continuous water temperatures were collected from the reach of the Connecticut River from below Cabot Station downstream to Mitch's Island, which is approximately 8 miles above Holyoke Dam (see Figure 2.1-1). Water temperature data from Sites 11 through 18 are compared and monthly plots are contained in

Appendix G. As demonstrated in the overview provided in Section 3.3.2 of this report, monthly average water temperatures were within 1.0°C at locations below Cabot Station (Sites 11 through 18).

Typical diurnal patterns were apparent. Some of the sites below Cabot Station were relatively shallow during the summer months, and therefore, the range of diurnal water temperatures was greater than at deeper sites. Figures 3.4.5-1 (Site 11 – 14) and 3.4.5-2 (Site 15 – 18) depict water temperatures during a period of high air temperature and low flow from May 15-31, 2015. Cabot Station discharge, Station No. 1 discharge, and USGS Montague gage flow are also shown on these charts. Note that Site 14 at Second Island was exposed to air during a period of low flows and the data were rejected.

Figures 3.4.5-3 (Site 11 – 14) and 3.4.5-4 (Site 15 – 18) depict water temperatures during a period of high air temperature and low flow from August 17 to September 8, 2015. Similar diurnal patterns are evident.

Hourly Rate of Change (RoC) for water temperature data was calculated for Sites 11 – 18 and presented as a monthly average and maximum for each site in Figure 3.4.5-5. Note that April was not included because not all sites were installed at the same time and flows were high. All sites below Cabot Station had an average hourly RoC at or below 0.21°C during May through November. The largest hourly temperature RoC observed was 1.53°C at Site 12 in May and 1.3°C at Site 16 in August.

Two 7-day periods were highlighted (i.e., August 21 – August 27 and September 2–September 9) as representative low flow, warm temperature periods when both peaking and stable flow conditions at Cabot Station were occurring. Figure 3.4.5-6a and Figure 3.4.5-7a display the water flow at the Montague USGS gage, Cabot Station discharge and temperatures for Sites 11 through 18 during these periods.

Companion figures showing the maximum and average hourly RoC for each day during these periods are shown in Figure 3.4.5-6b and Figure 3.4.5-7b. Daily average RoC during the two periods are similar regardless of Cabot Station operations. The maximum hourly temperature RoC experienced was 1.27°C at Site 16 August 24, slightly higher than 0.9°C at the same site when Cabot Station was near minimum discharge for the entire day.

During September 2-9, the average RoC was highest (~0.3°C/hr) at Site 16 and generally between 0.1-0.25°C/hr at other sites during this period. The maximum hourly temperature RoC experienced from September 2-9 was approximately 0.9°C, always at Site 16 (see Figure 3.4.5-7b). Average and maximum RoC values are similar each day during this period regardless of Cabot Station operations. The shallow nature of some of these areas in the Connecticut River downstream of the Project are susceptible to higher solar radiation and therefore experience more rapid warming and cooling compared to deeper areas of the river.

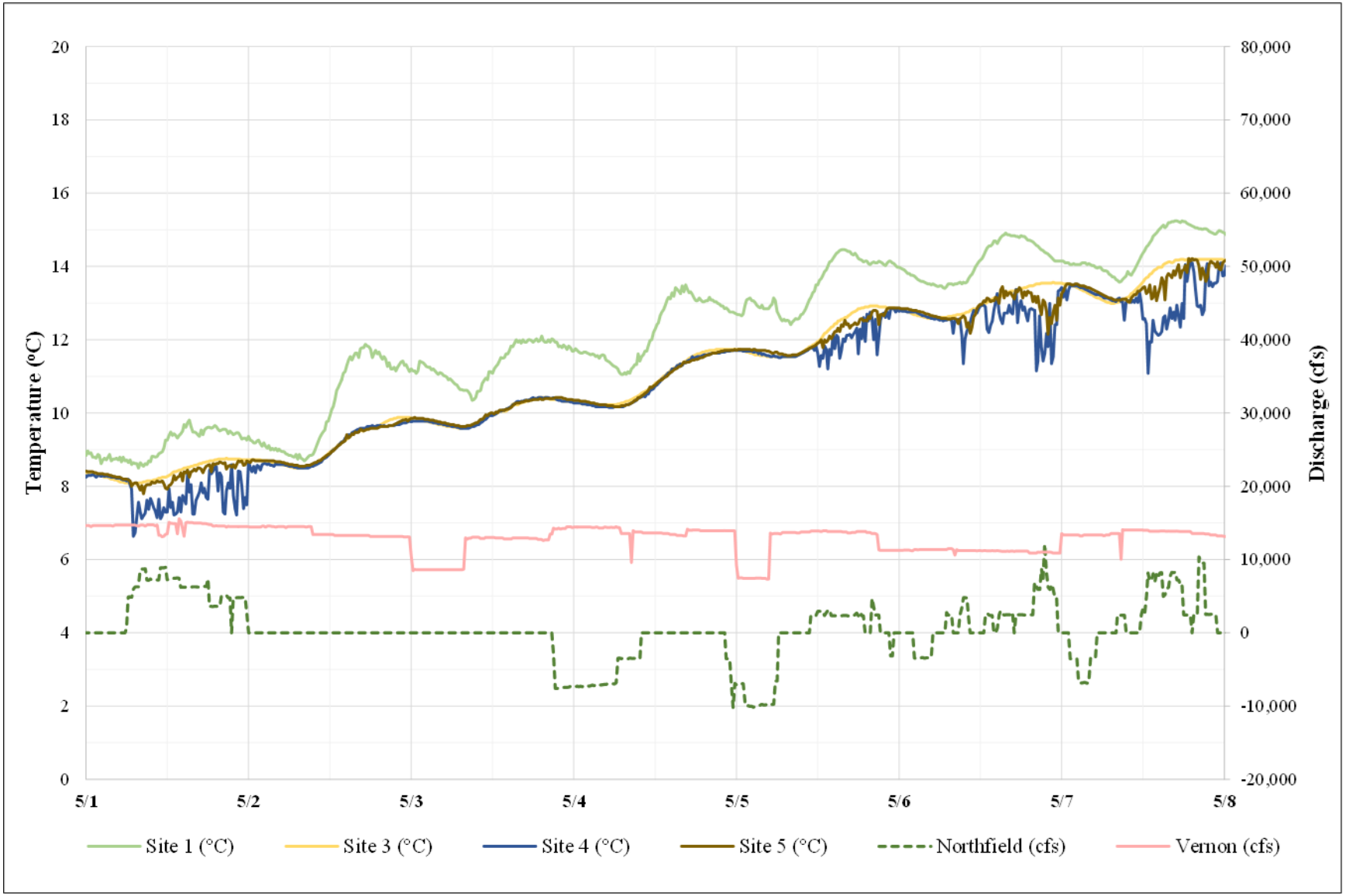


Figure 3.4-1-1: Water Temperature in TFI in Comparison to Vernon and Northfield Mountain Operations (May 1 – May 7, 2015)

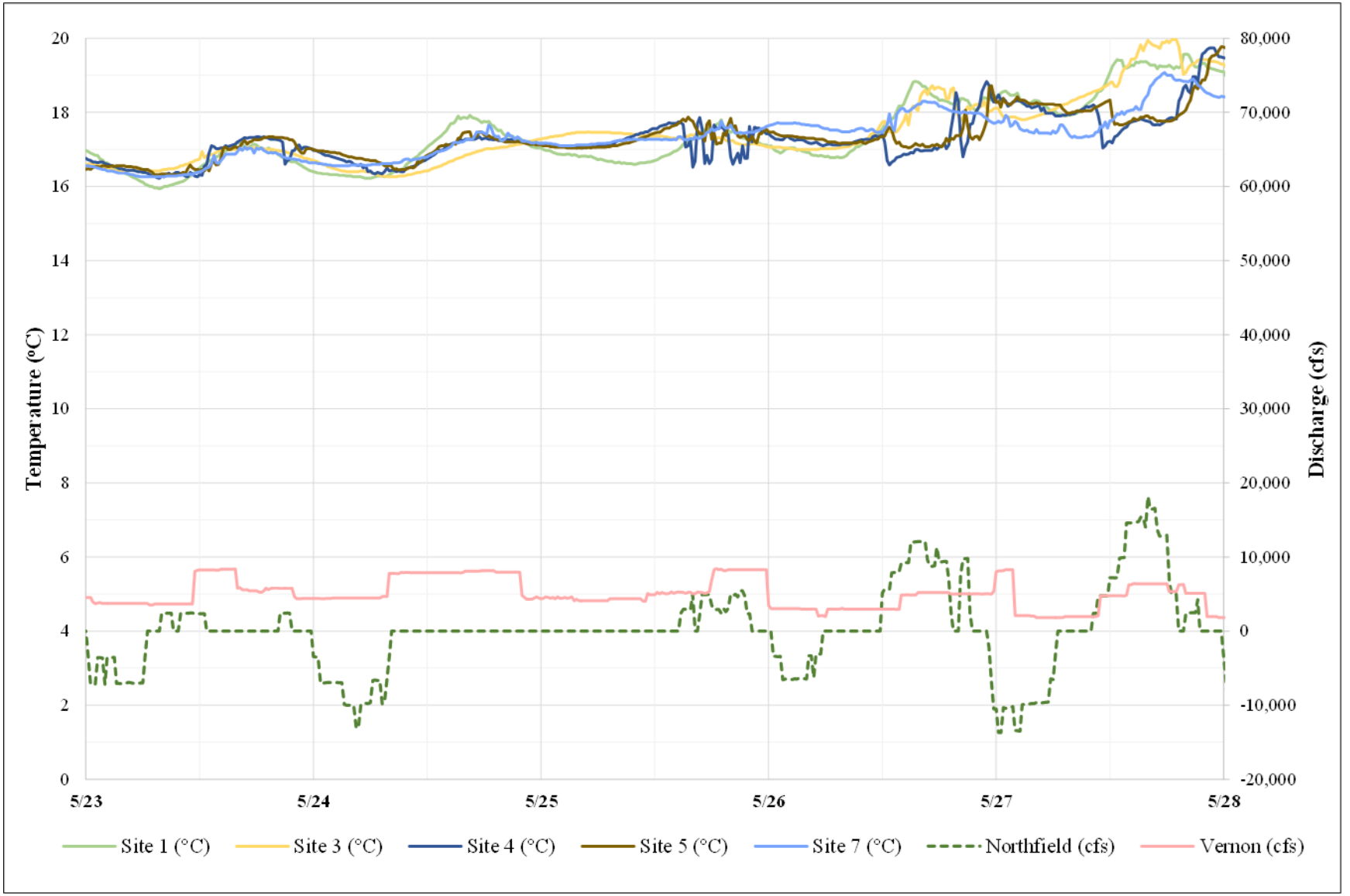


Figure 3.4.1-2a: Water Temperature in TFI in Comparison to Vernon and Northfield Mountain Operations (May 23 – May 27, 2015)

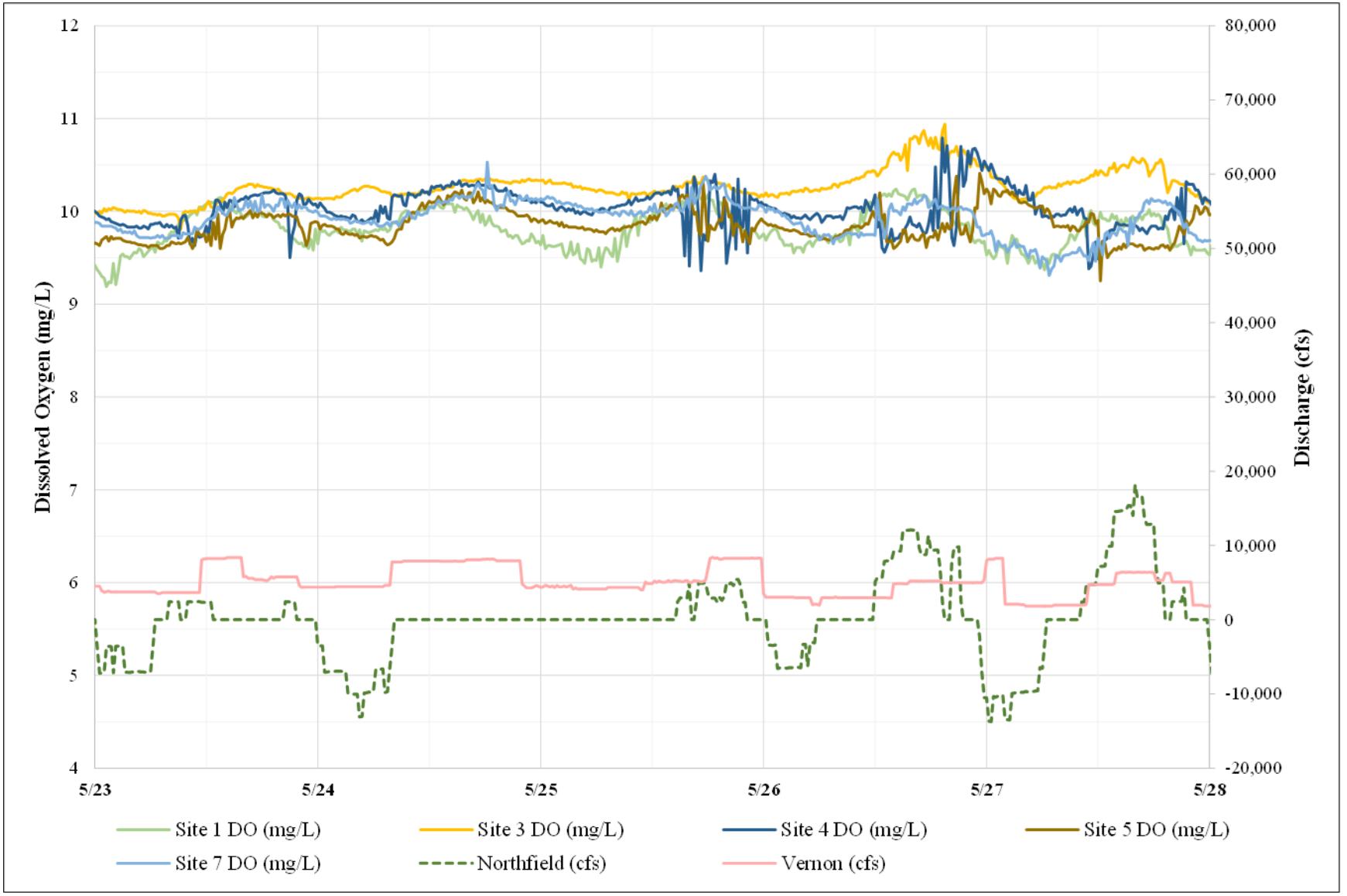


Figure 3.4.1-2b: DO Concentration in TFI in Comparison to Vernon and Northfield Mountain Operations (May 23 – May 27, 2015)

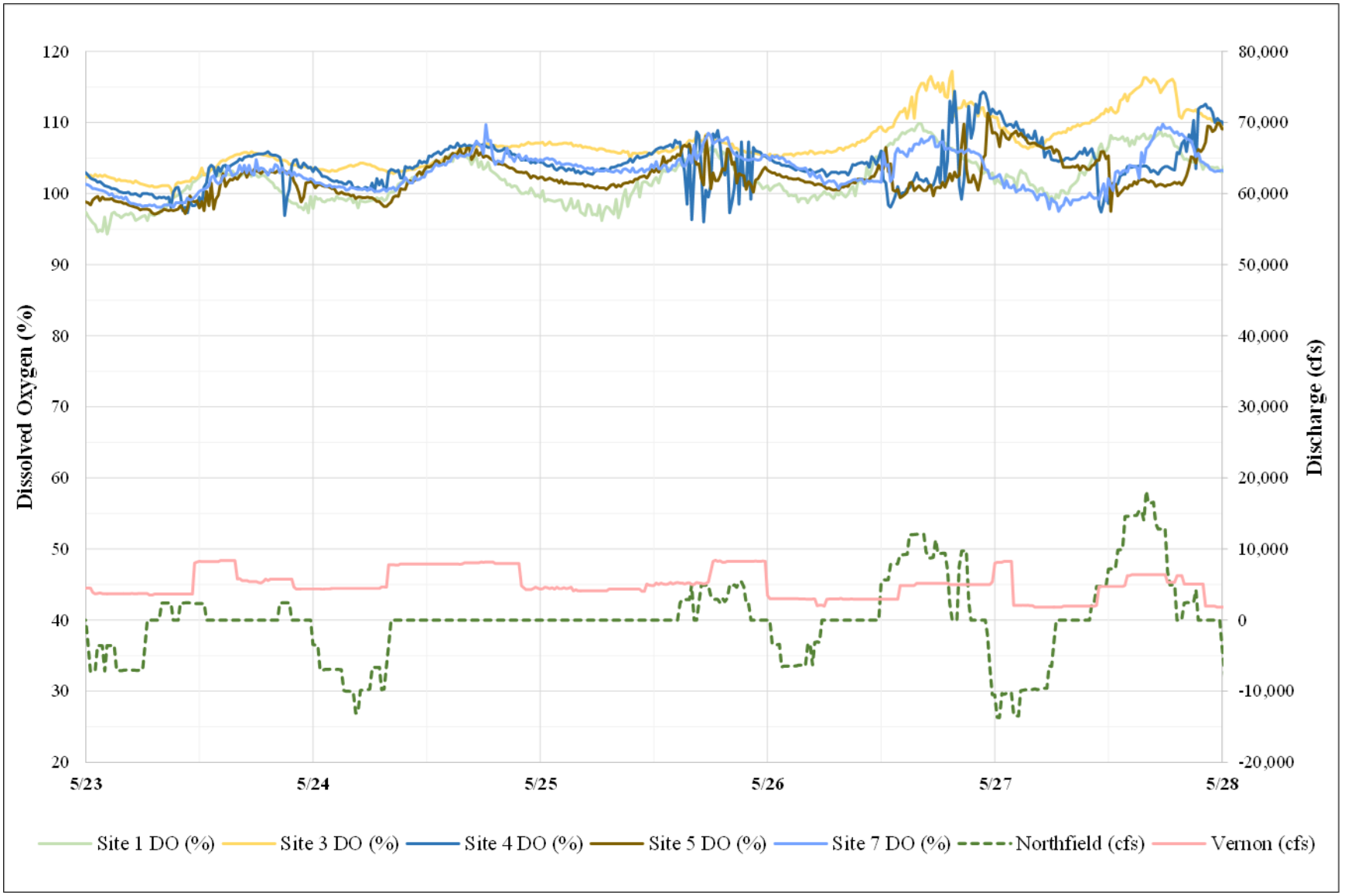


Figure 3.4.1-2c: DO %sat in TFI in Comparison to Vernon and Northfield Mountain Operations (May 23 – May 27, 2015)

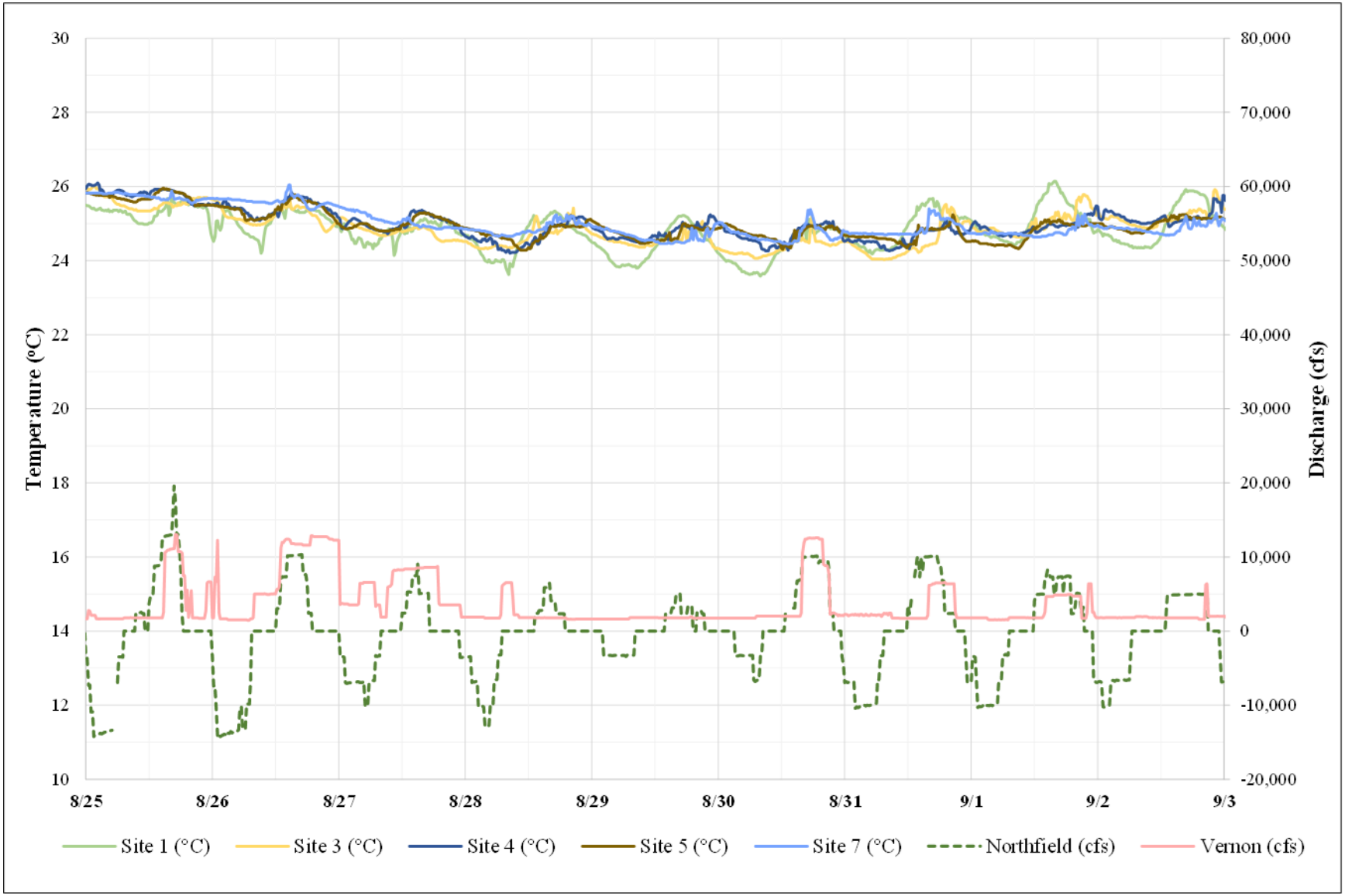


Figure 3.4.1-3a: Water Temperature in TFI in Comparison to Vernon and Northfield Mountain Operations (August 25 – September 2, 2015)

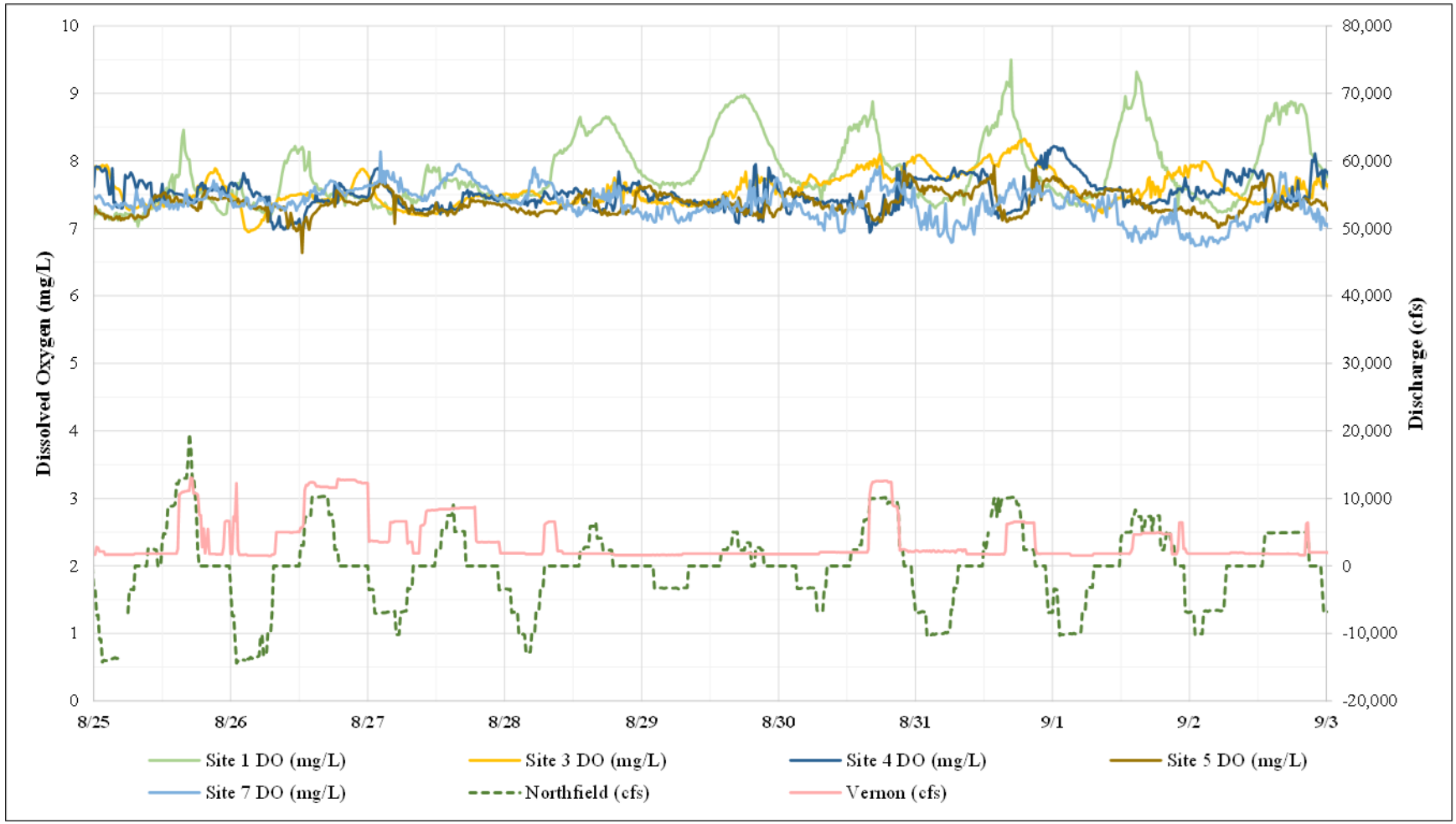


Figure 3.4.1-3b: DO Concentration in TFI in Comparison to Vernon and Northfield Mountain Operations (August 25 – September 2, 2015)

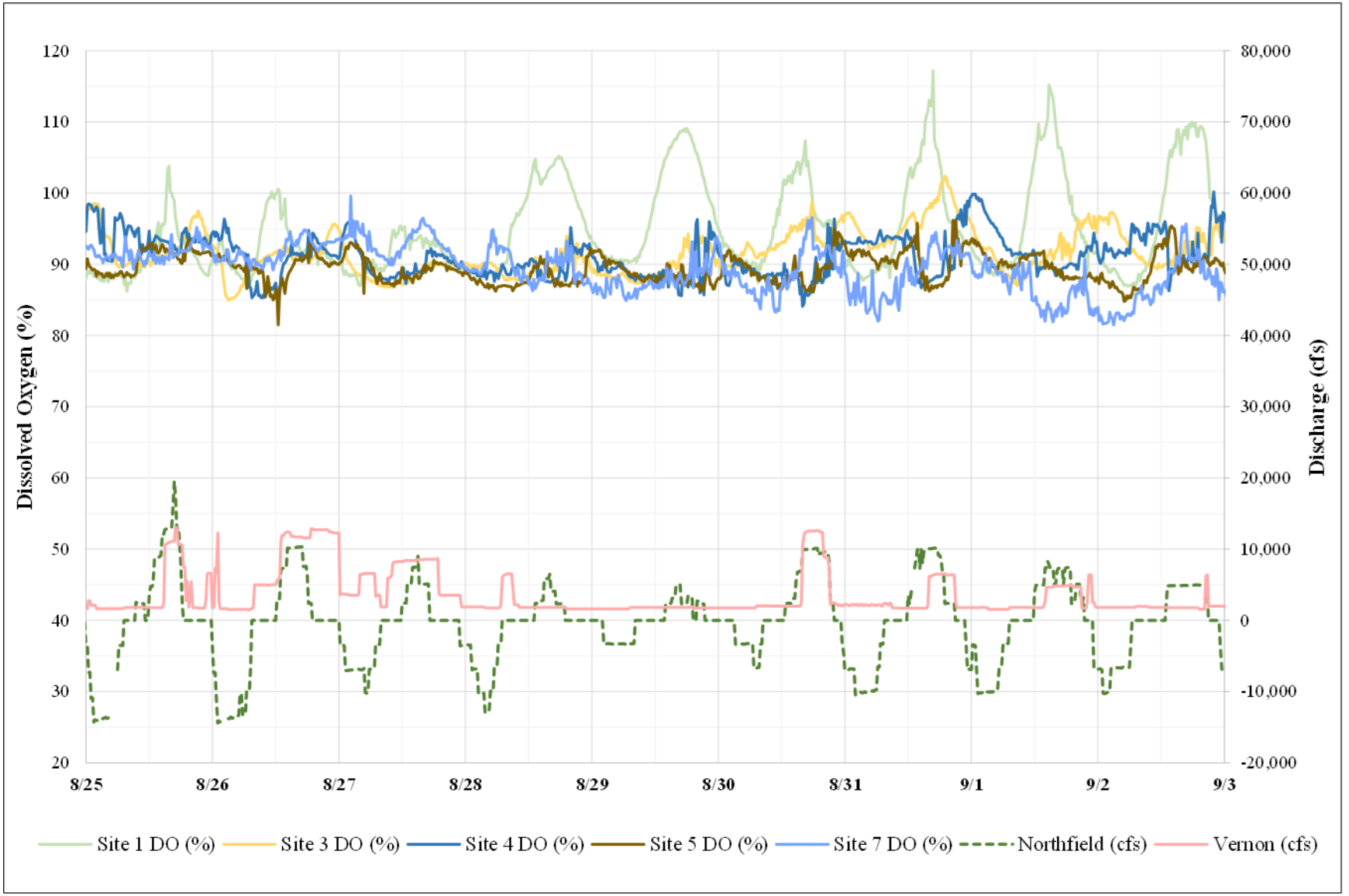


Figure 3.4.1-3c: DO %sat in TFI in Comparison to Vernon and Northfield Mountain Operations (August 25 – September 2, 2015)

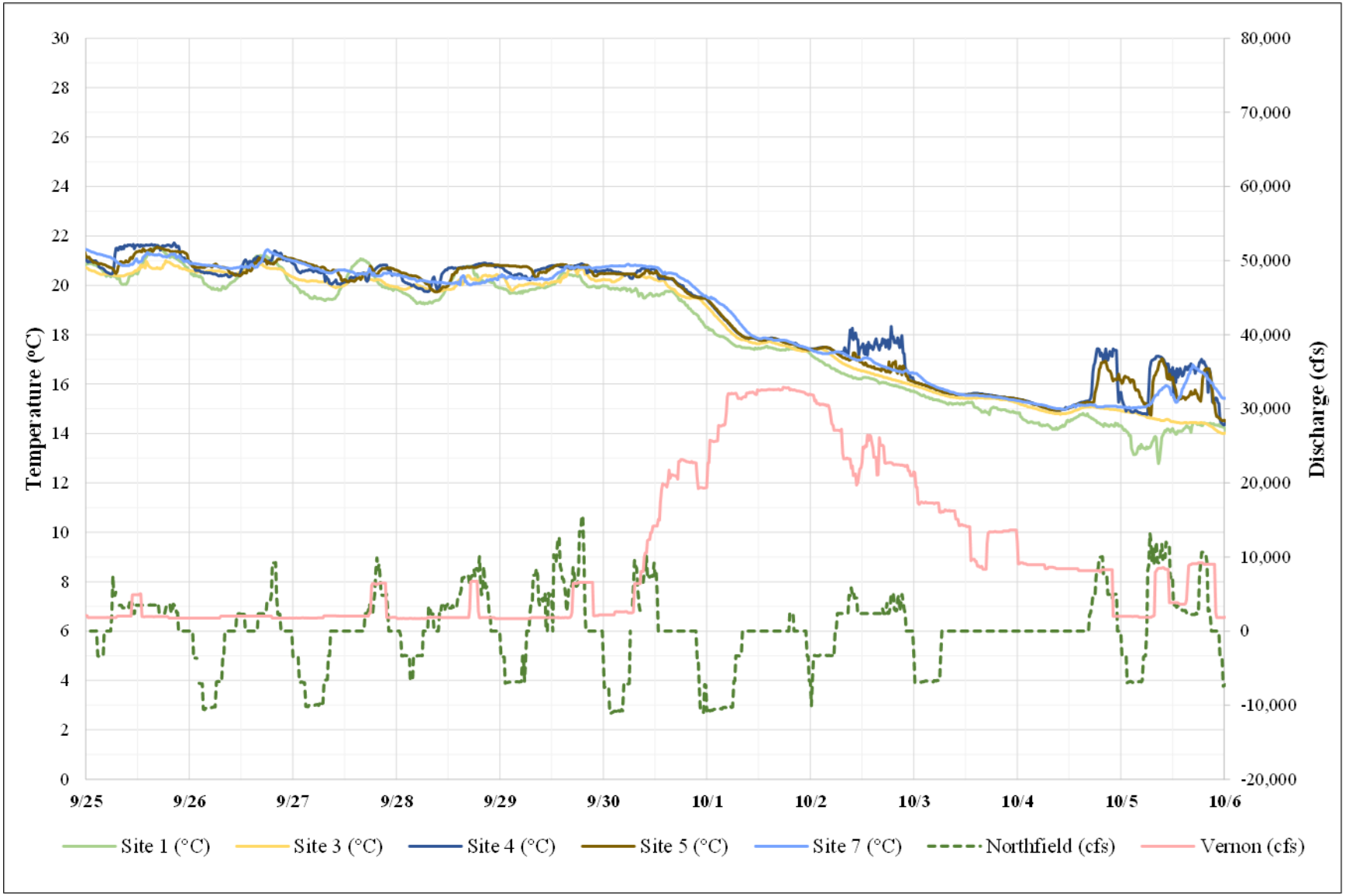


Figure 3.4.1-4: Water Temperature in TFI in Comparison to Vernon and Northfield Mountain Operations (Sept 25 – Oct 5, 2015)

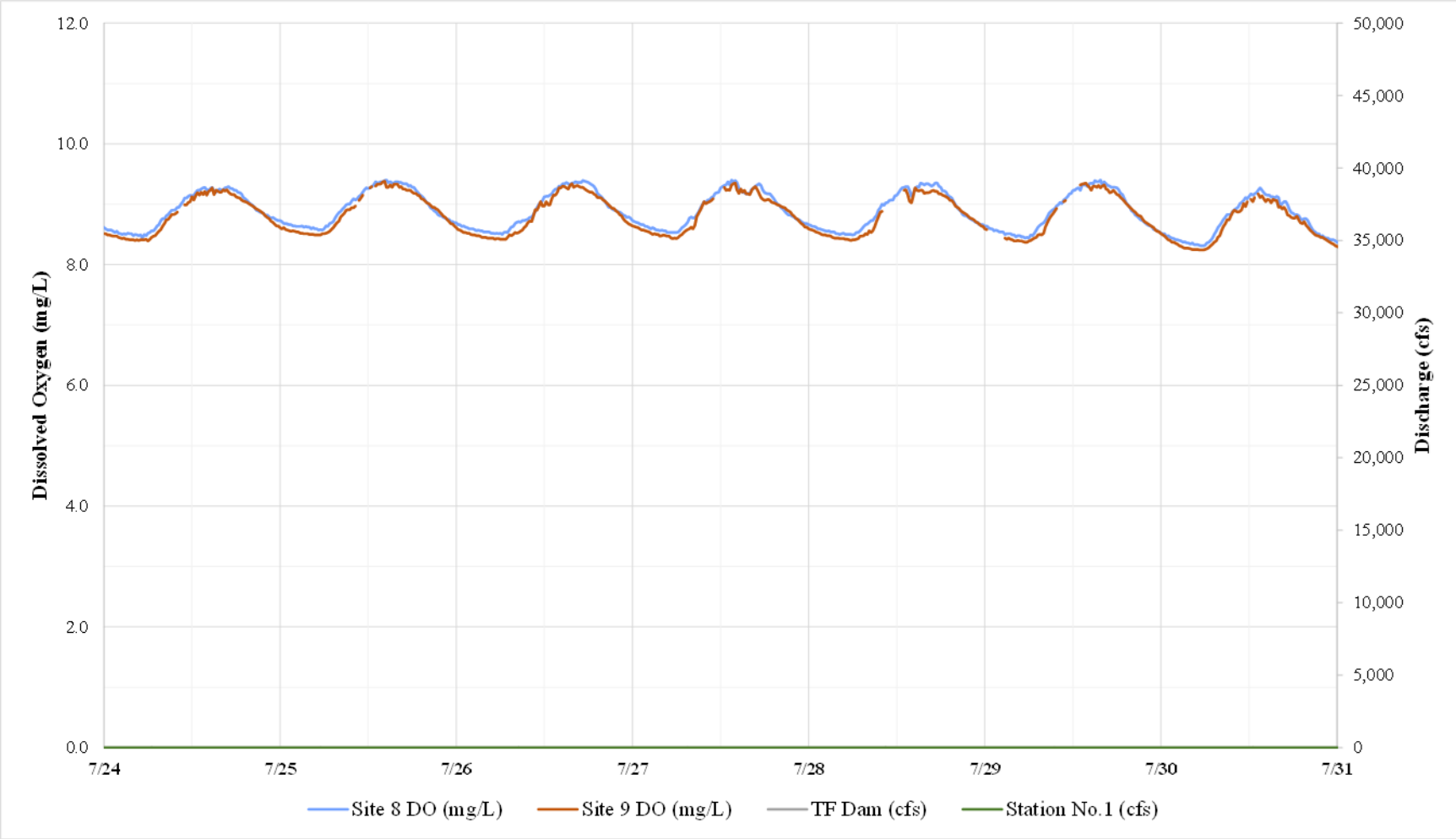


Figure 3.4.2-1a: Typical Diurnal DO Patterns in the Bypass Reach During Minimum Flow Conditions, July 24-30, 2015

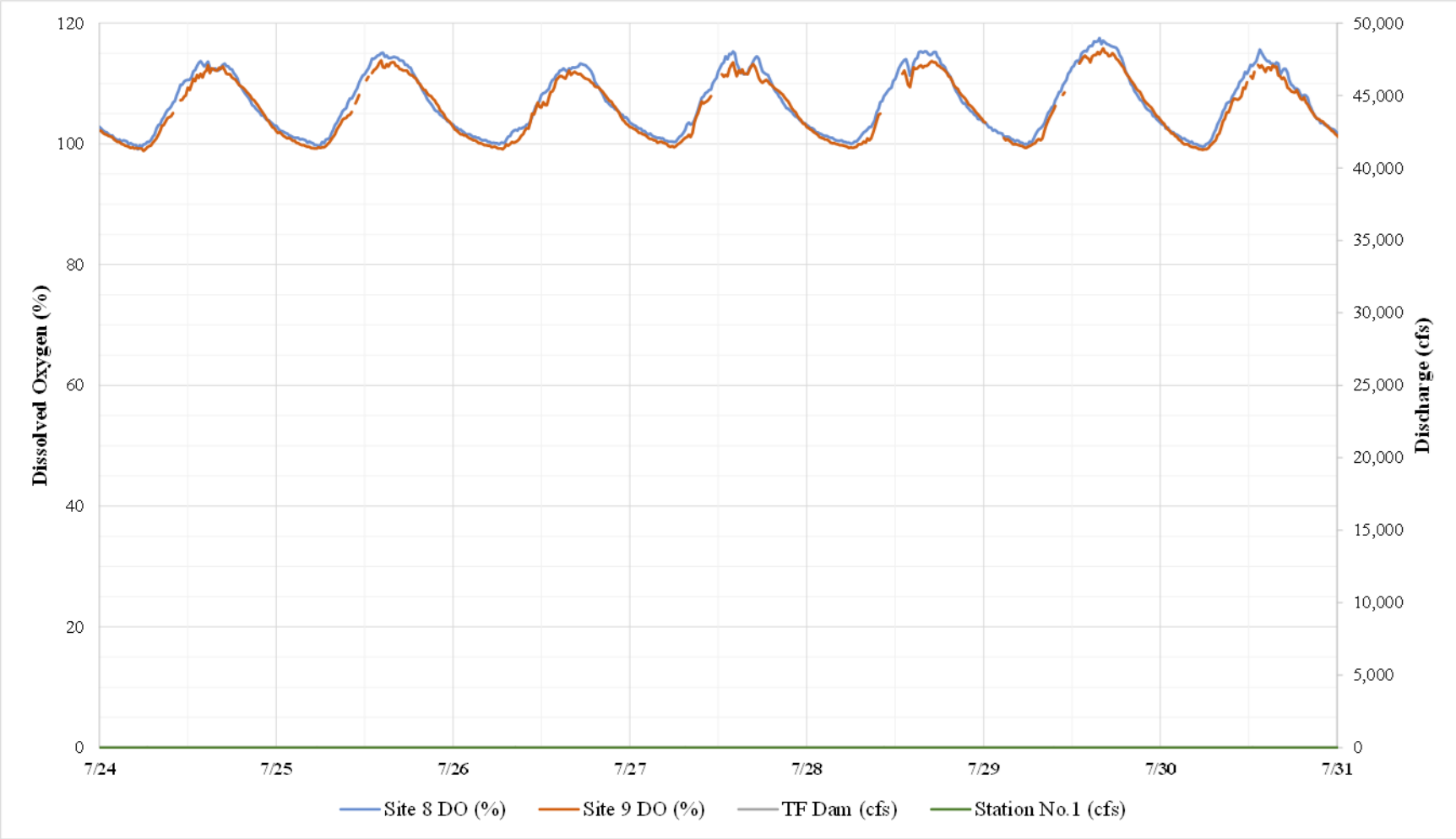


Figure 3.4.2-1b: Typical Diurnal DO Saturation Patterns in the Bypass Reach During Minimum Flow Conditions, July 24-30, 2015

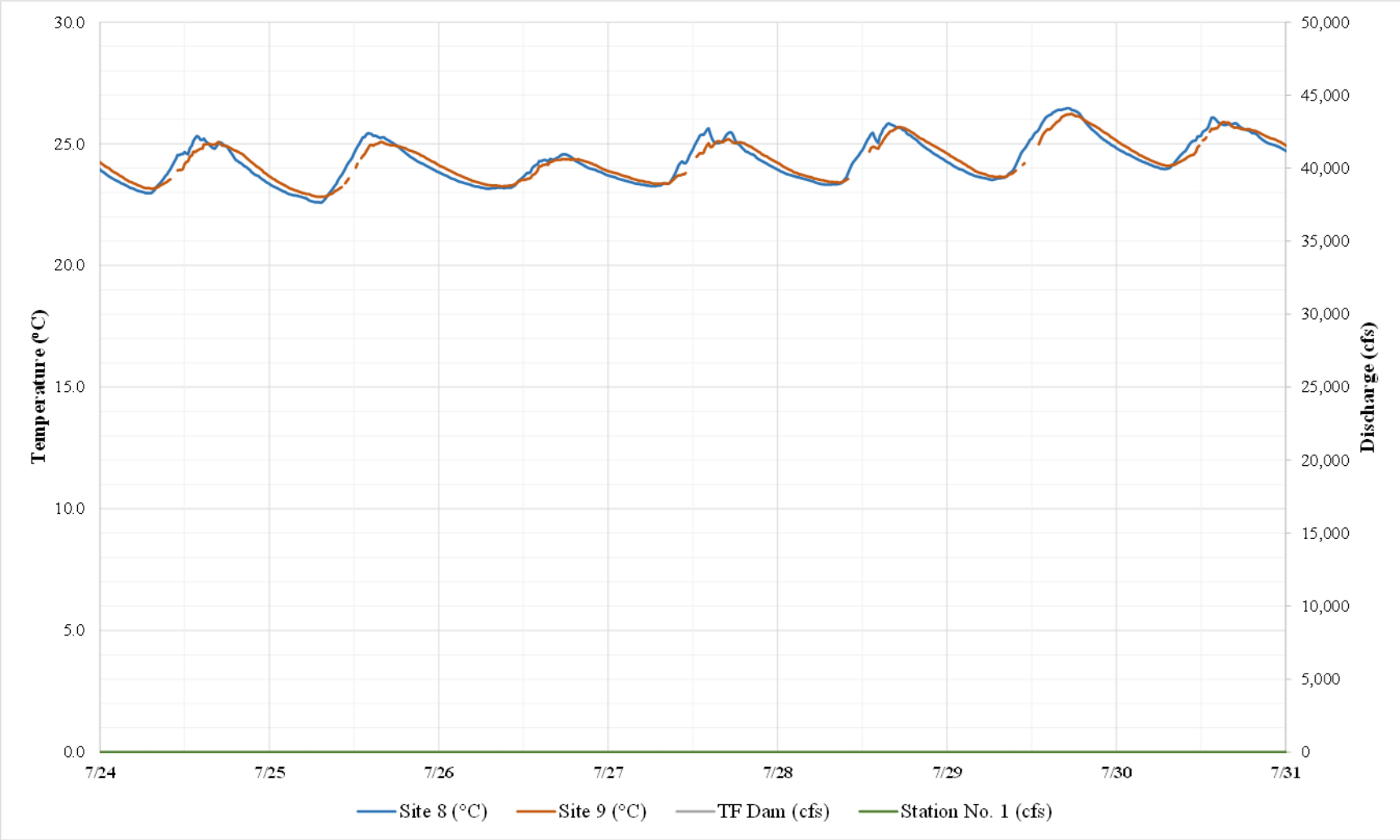


Figure 3.4.2-1c: Typical Diurnal Temperature Patterns in the Bypass Reach During Minimum Flow Conditions, July 24-30, 2015

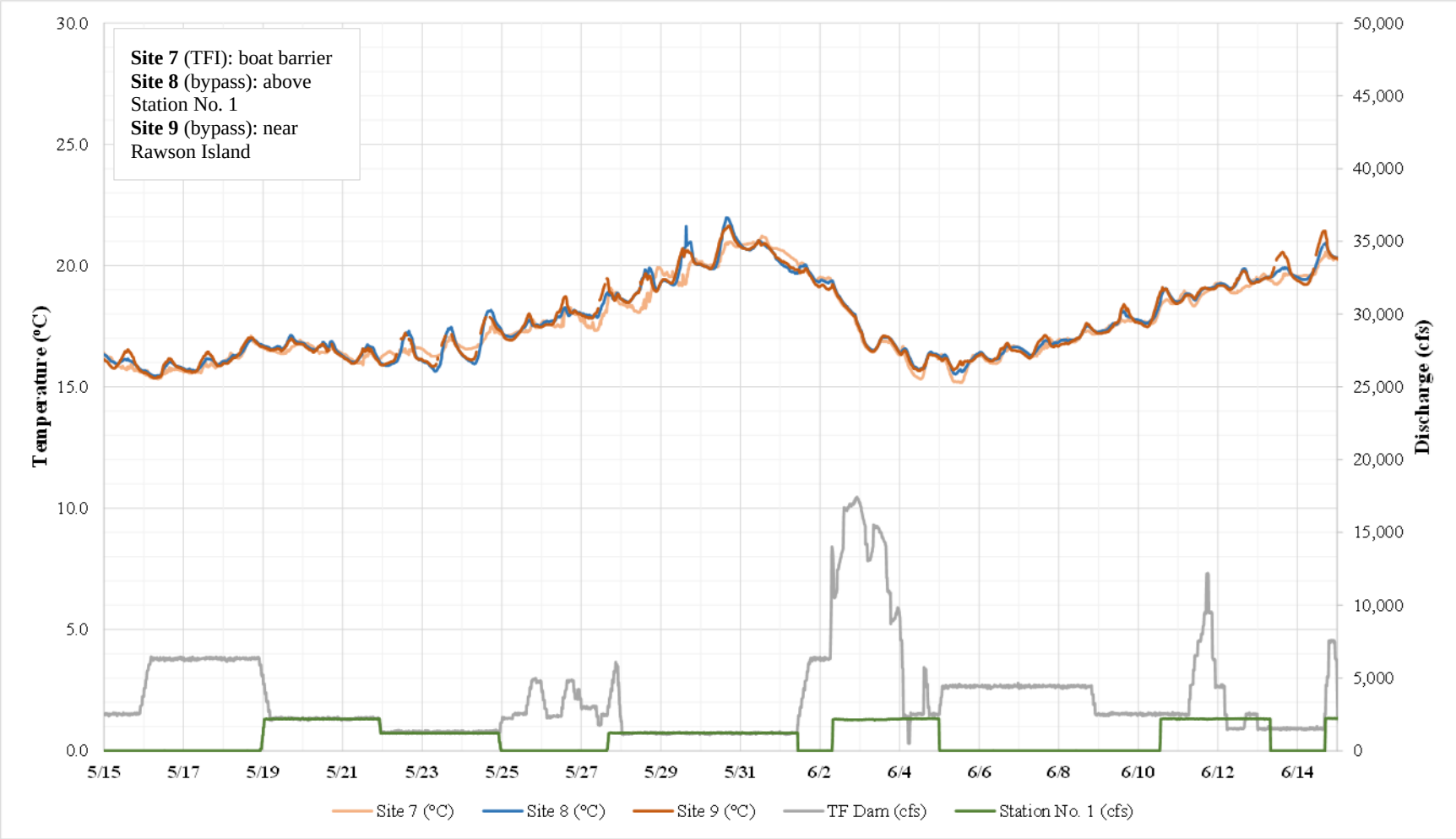


Figure 3.4.2-2a: Bypass Reach Temperature compared against Turners Falls Dam Spillage and Station No. 1 Generation (May 15 – June 14, 2015)

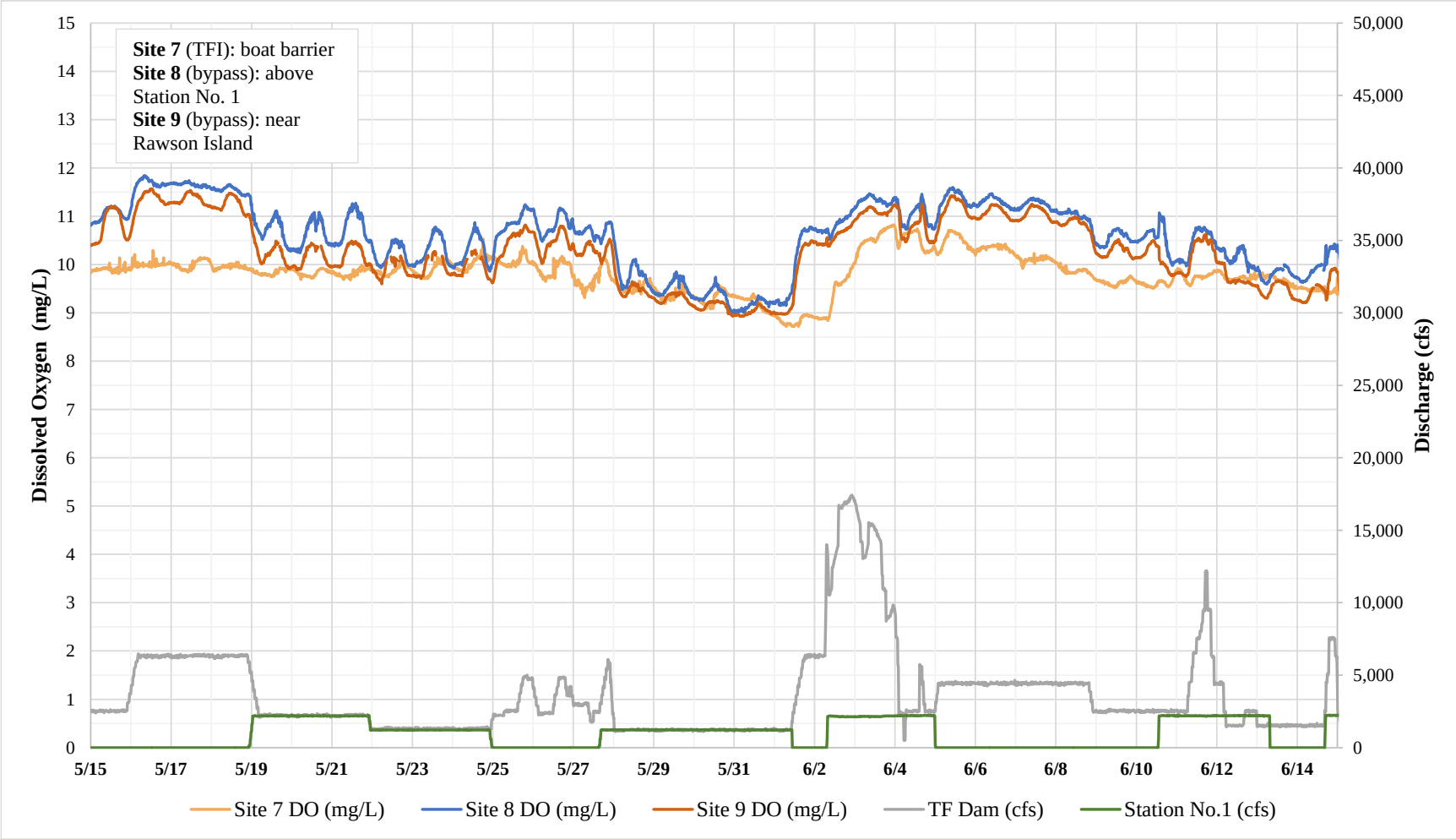


Figure 3.4.2-2b: Bypass Reach DO Concentration compared Against Turners Falls Dam Spillage and Station No. 1 Generation (May 15-June 14, 2015)

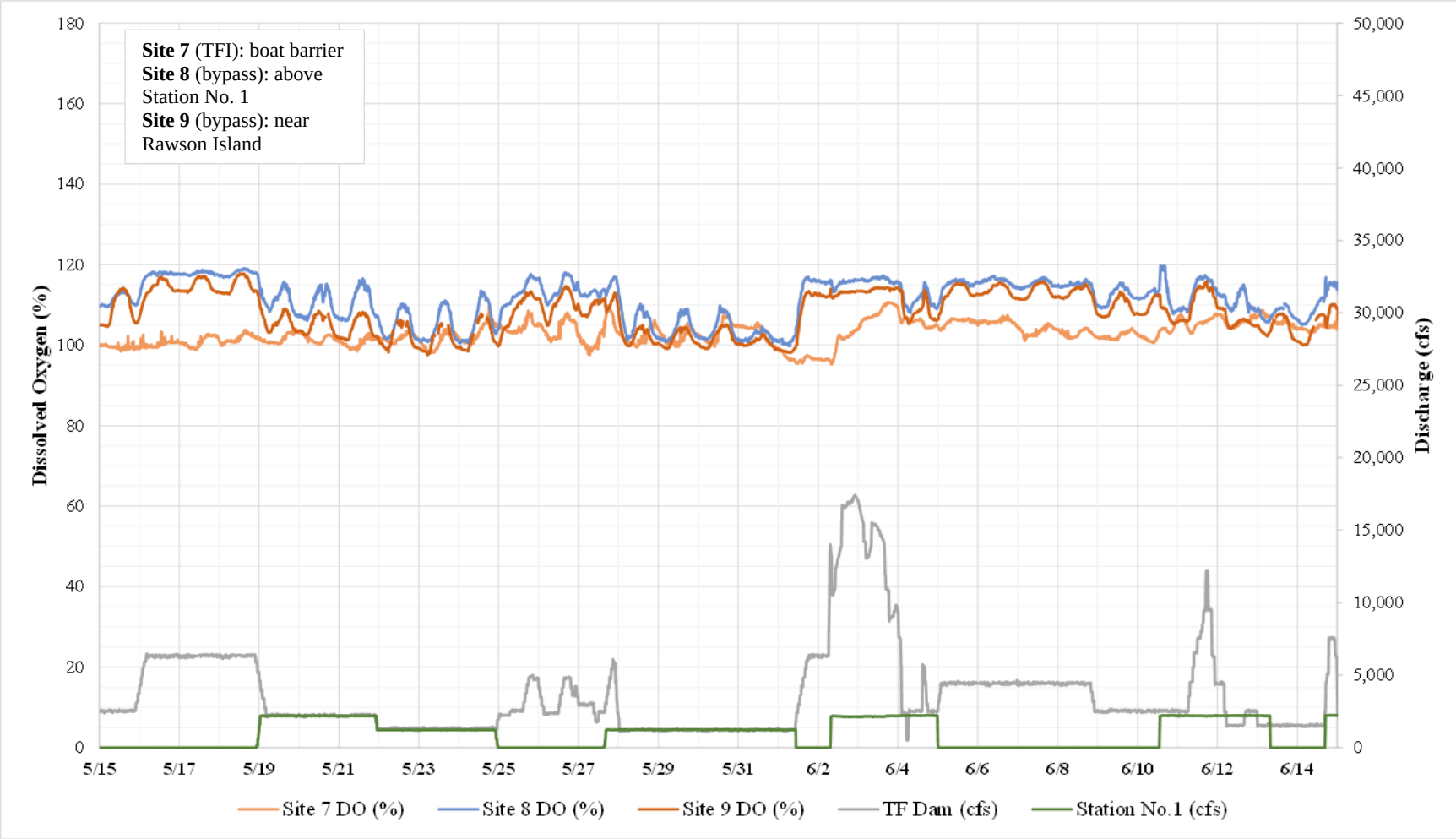


Figure 3.4.2-2c: Bypass Reach DO Saturation compared against Turners Falls Dam Spillage and Station No. 1 Generation (May 15 – June 14, 2015)

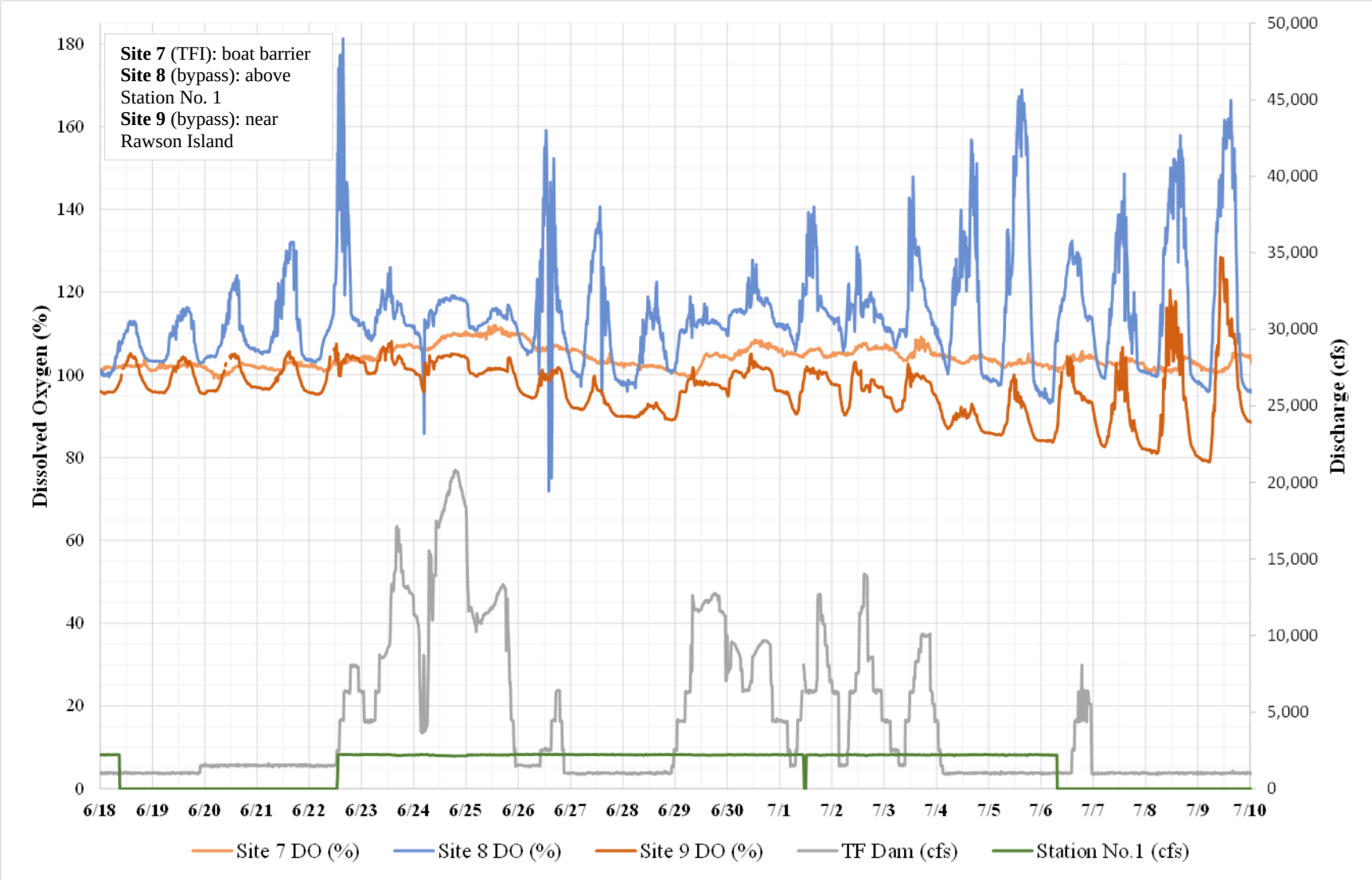


Figure 3.4.2-3: DO Percent Saturation in the Bypass Reach (June 18 – July 9, 2015)

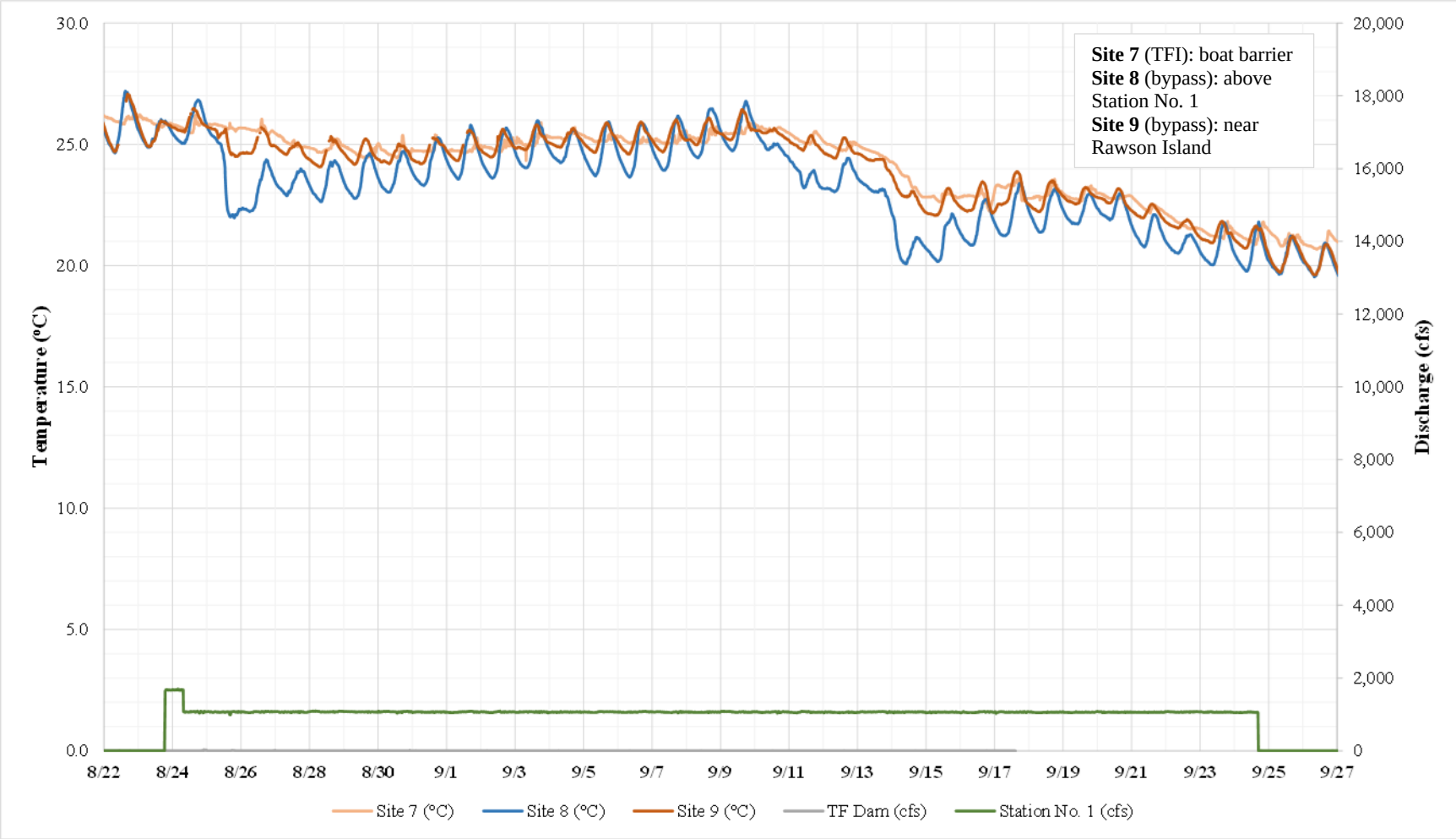


Figure 3.4.2-4a: Bypass Reach Temperature compared against Station No. 1 Generation (August 22 – September 26, 2015)

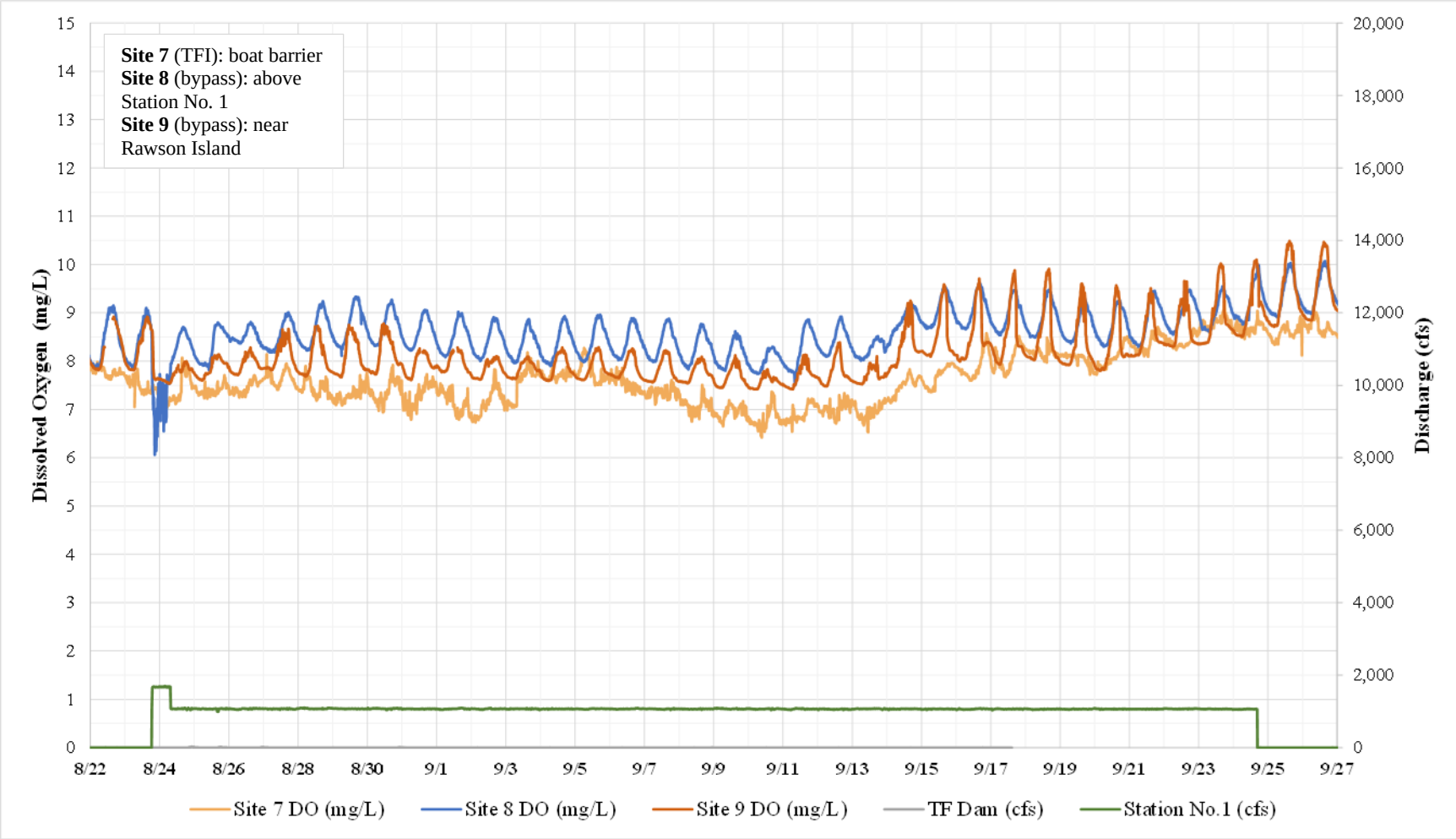


Figure 3.4.2-4b: Bypass Reach DO Concentration compared against Station No. 1 Generation (August 22 – September 26, 2015)

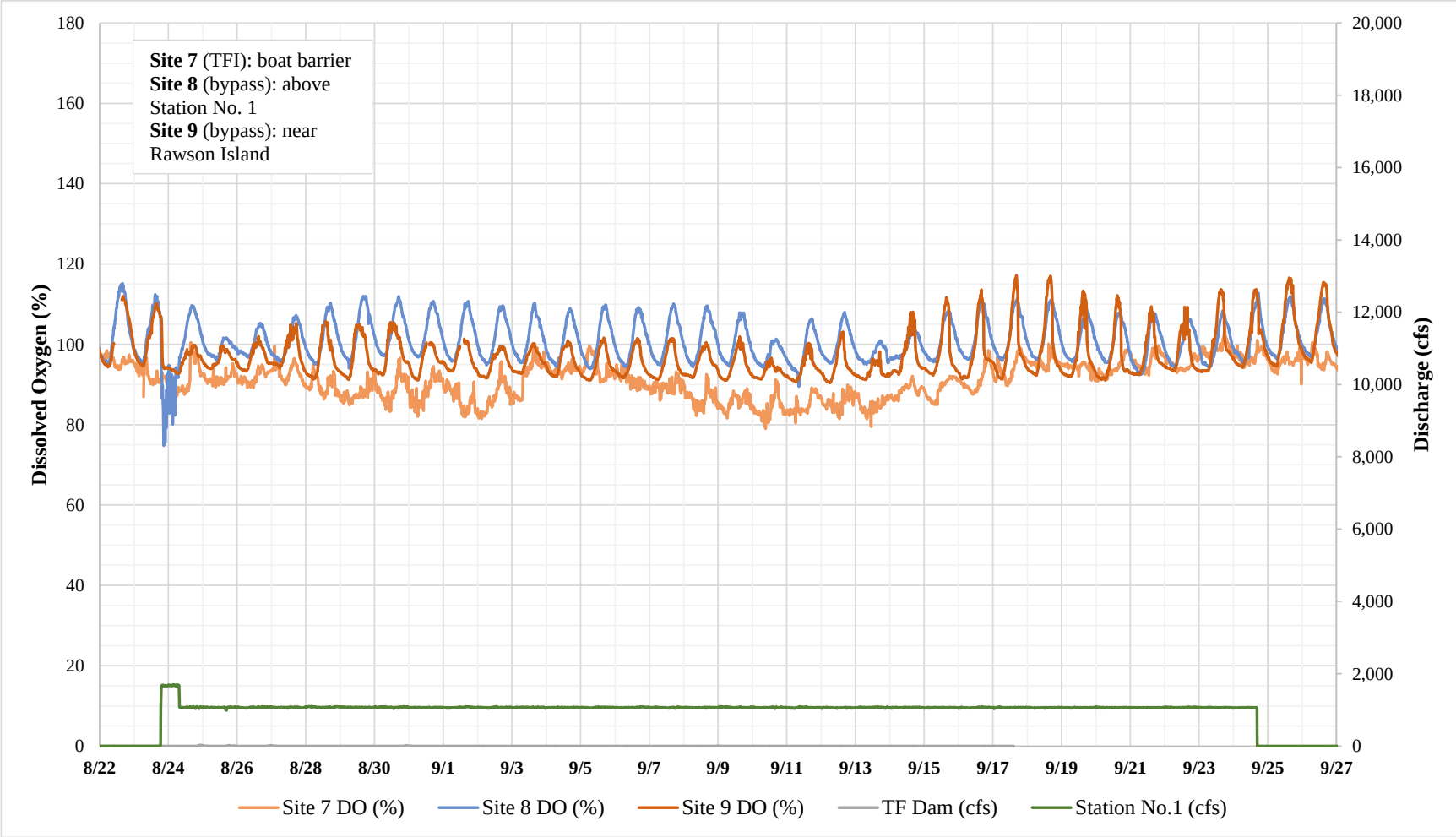


Figure 3.4.2-4c: Bypass Reach DO Percent Saturation compared against Station No. 1 Generation (August 22 – September 26, 2015)

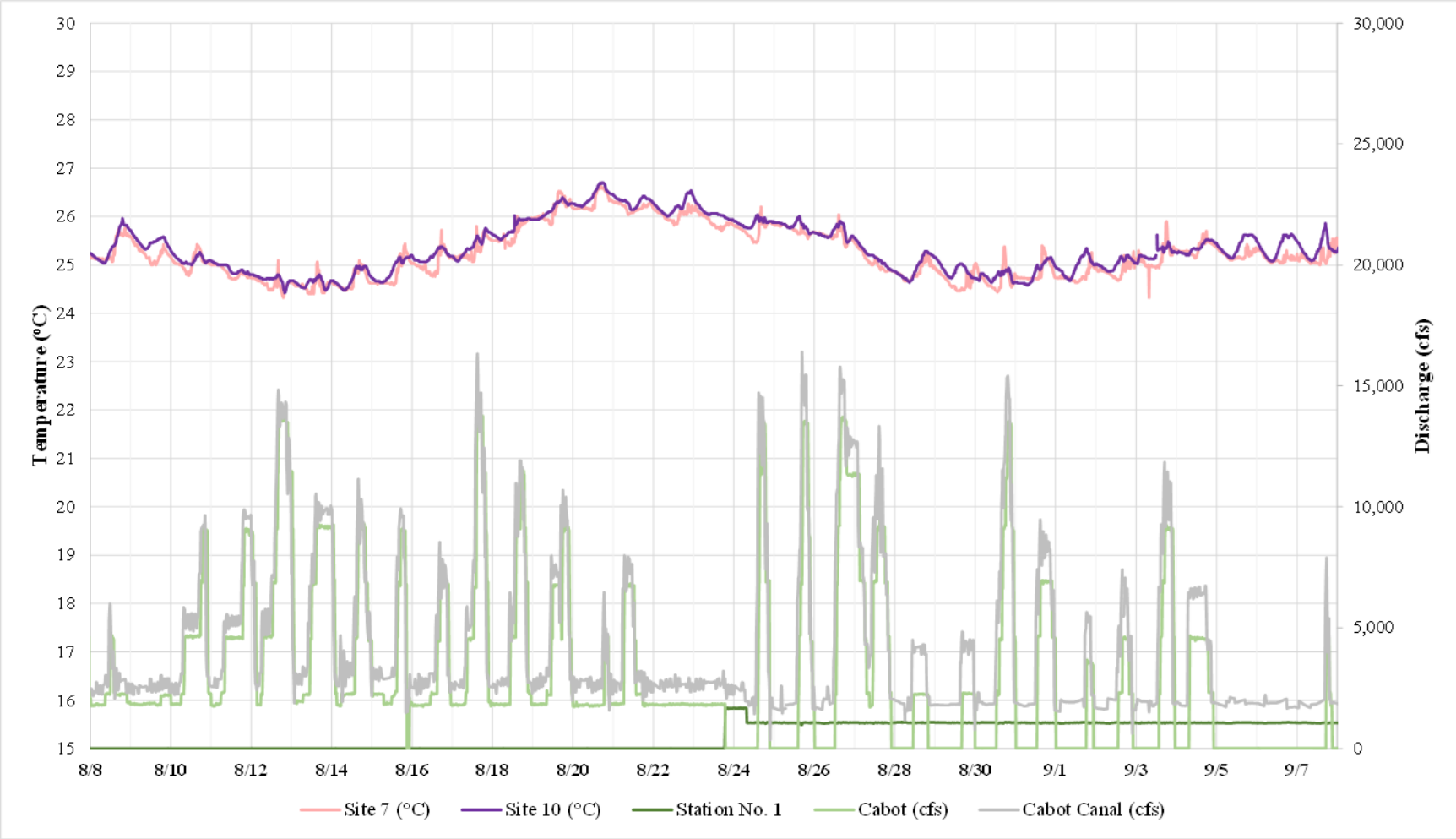


Figure 3.4.3-1a: Water Temperature in the Power Canal (August 8 – September 7, 2015)

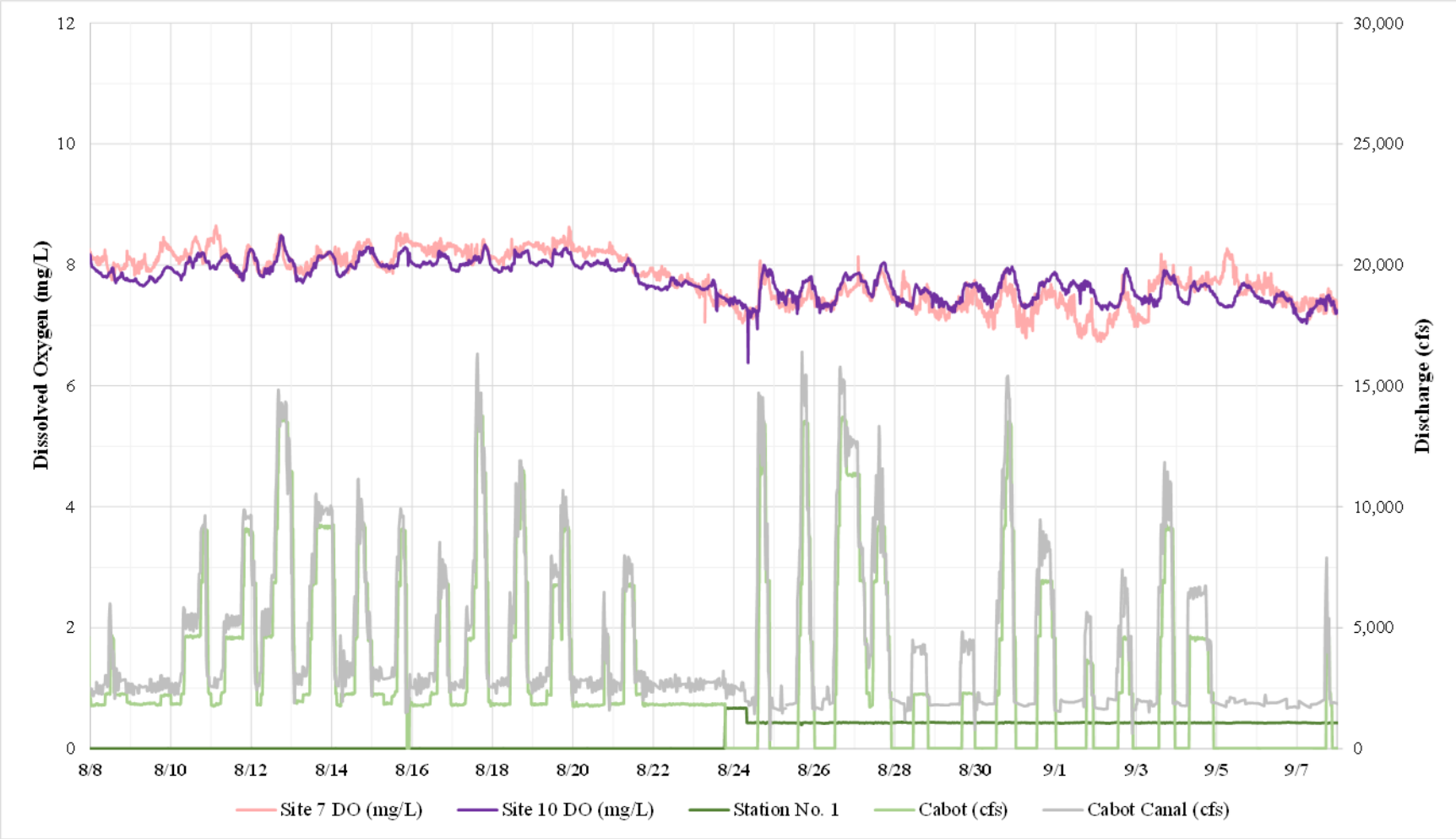


Figure 3.4.3-1b: Diurnal DO Patterns in the Power Canal in Comparison to Operations Data (August 8 – September 7, 2015)

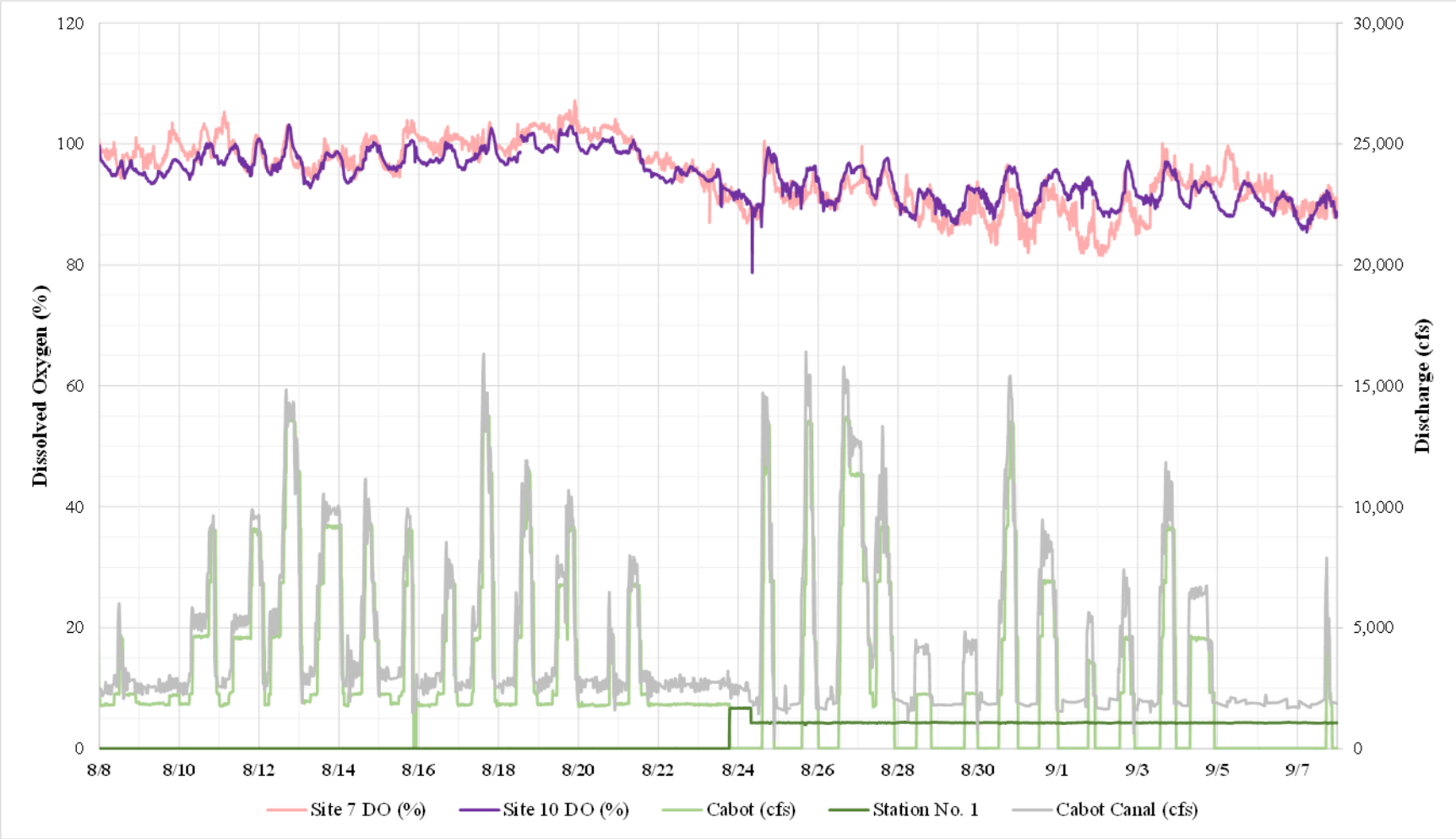


Figure 3.4.3-1c: Diurnal DO Saturation Patterns in the Power Canal in Comparison to Operations Data (August 8 – September 7, 2015)

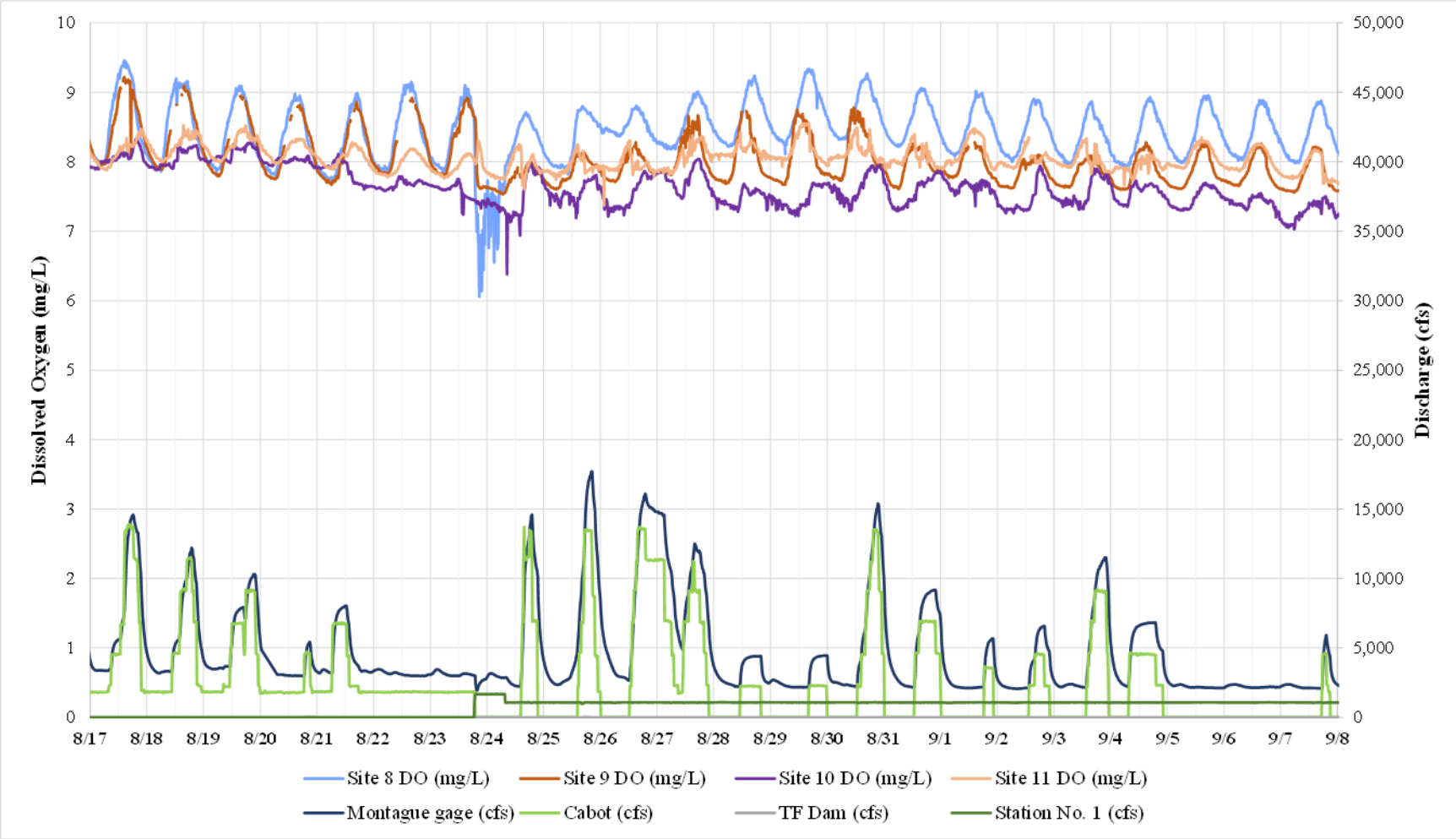


Figure 3.4.4-1a: DO Concentration at Site 11 Downstream of Cabot Station (August 17 – September 7, 2015)

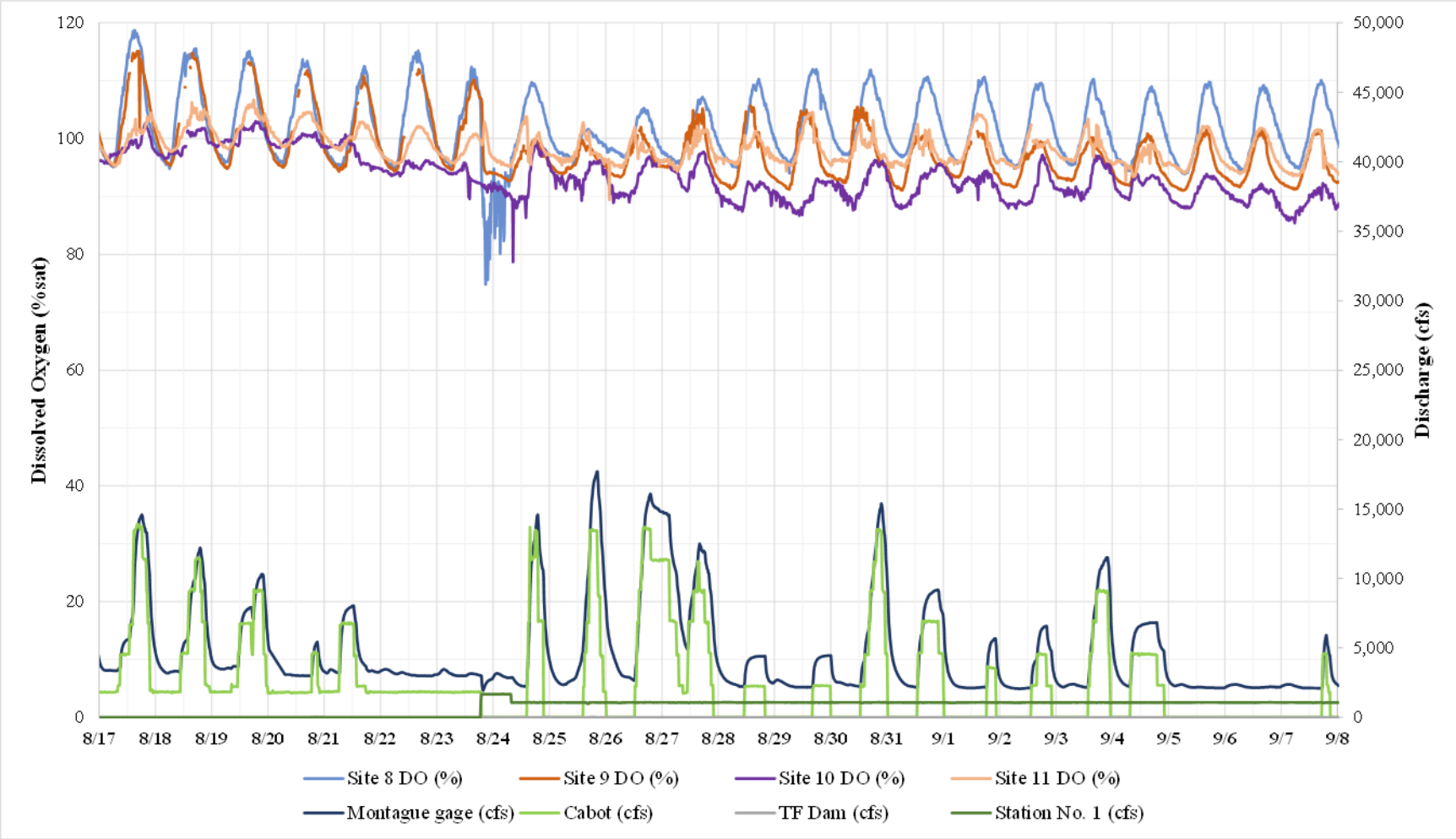


Figure 3.4.4-1b: DO Percent Saturation at Site 11 Downstream of Cabot Station (August 17 – September 7, 2015)

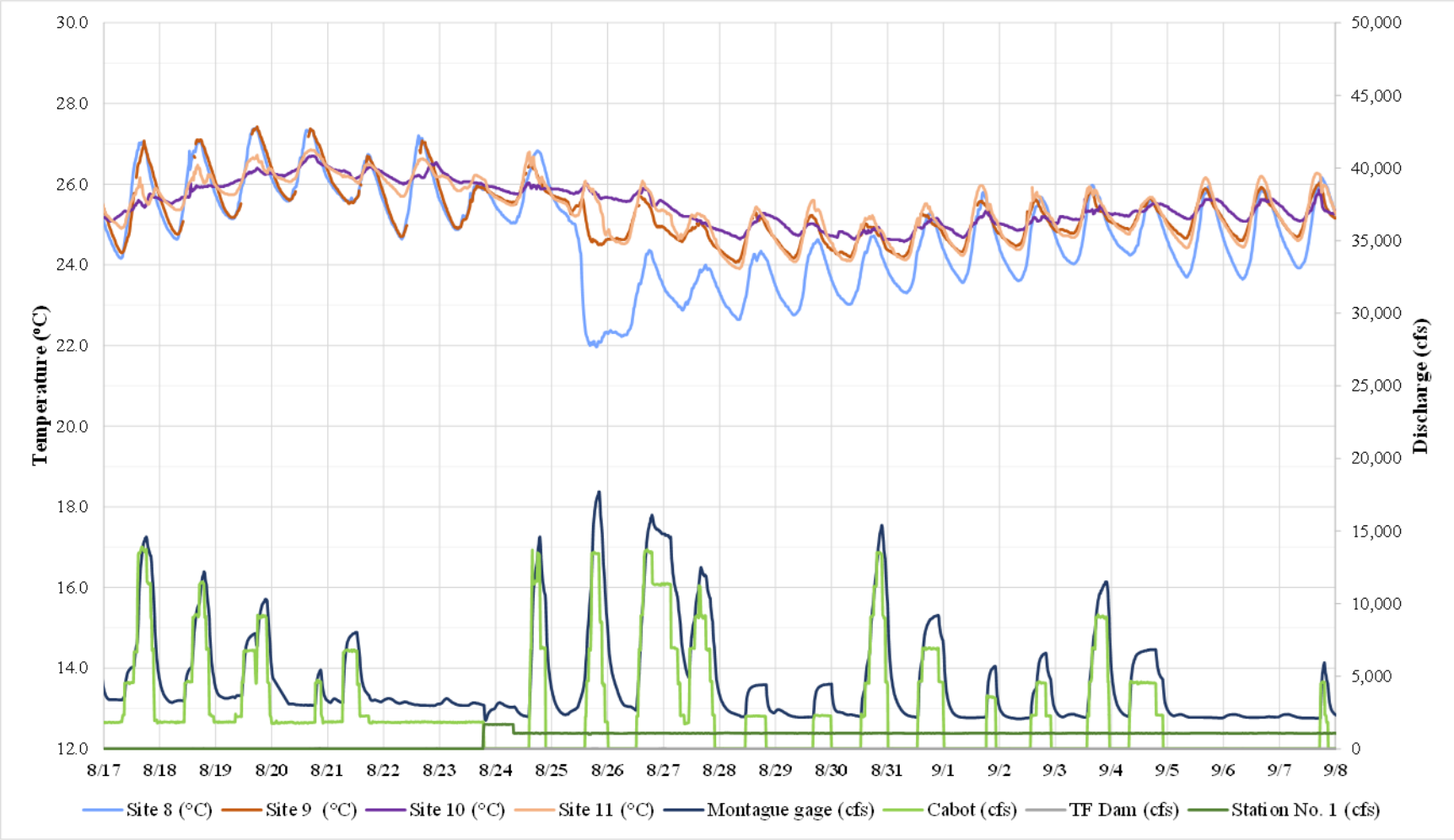


Figure 3.4.4-1c: Water Temperature at Site 11 Downstream of Cabot Station (August 17 – September 7, 2015)

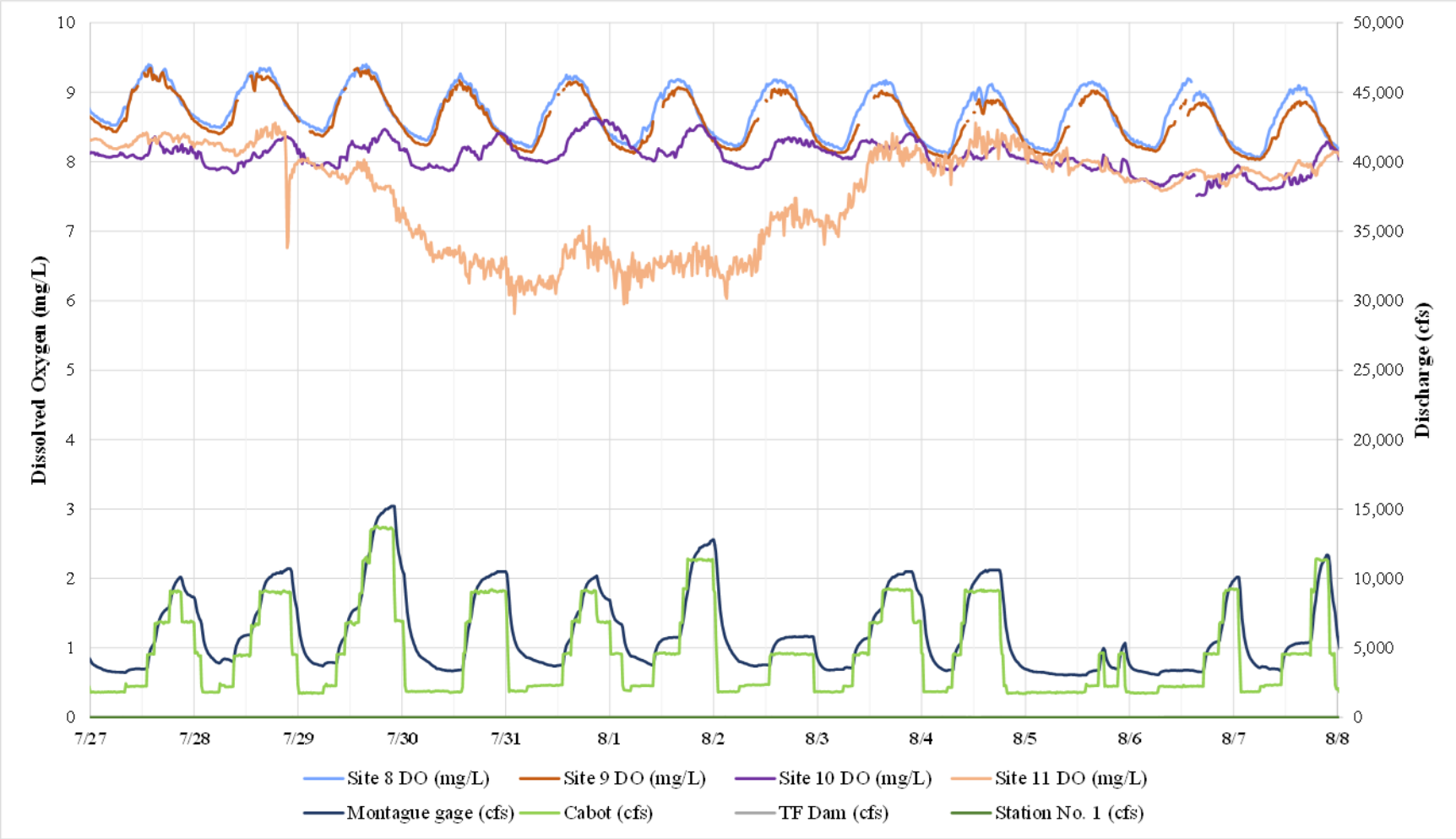


Figure 3.4.4-2a: DO Concentration at Site 11 Downstream of Cabot Station (July 27-August 7, 2015)

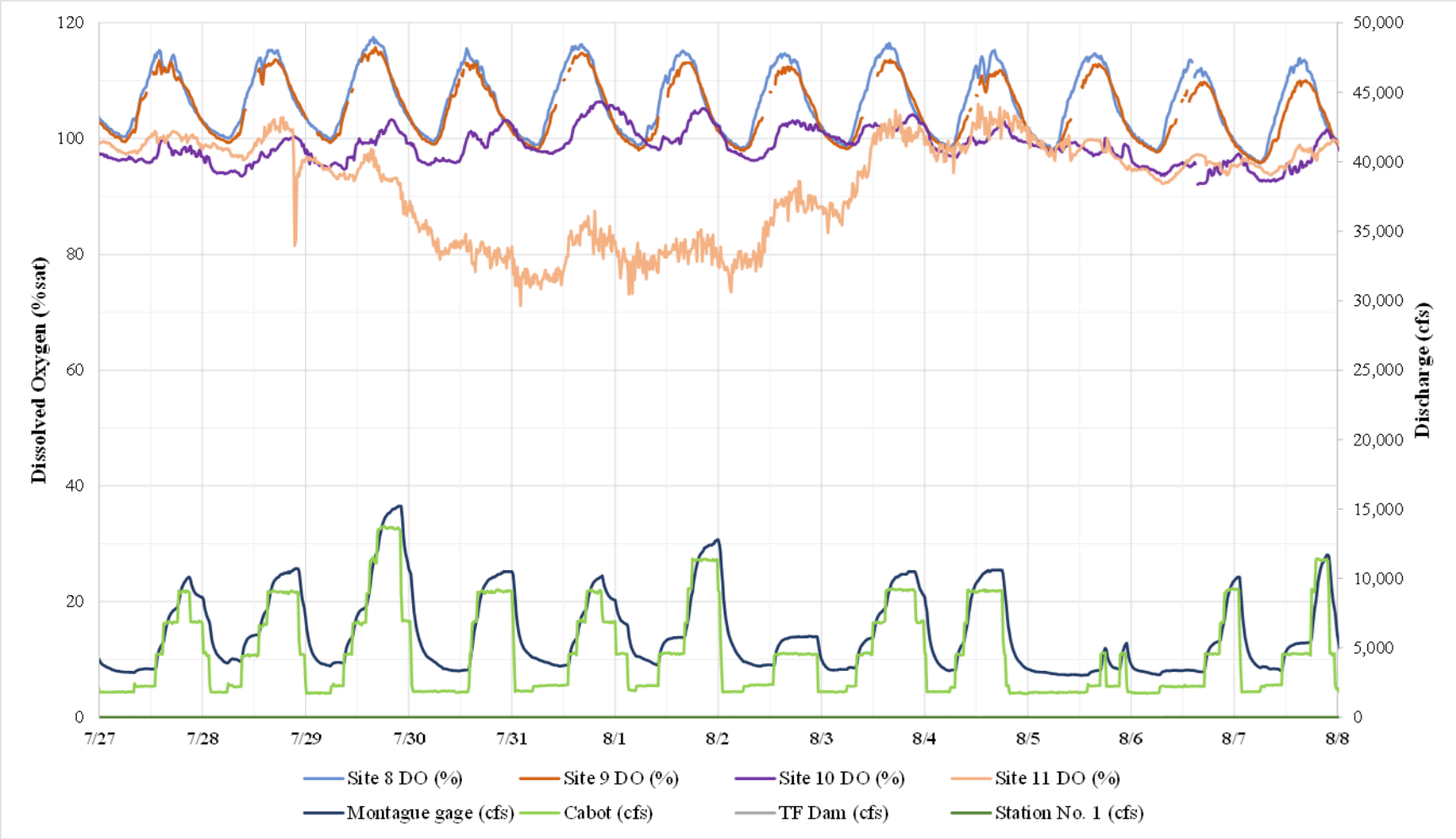


Figure 3.4.4-2b: DO Percent Saturation at Site 11 Downstream of Cabot Station (July 27-August 7, 2015)

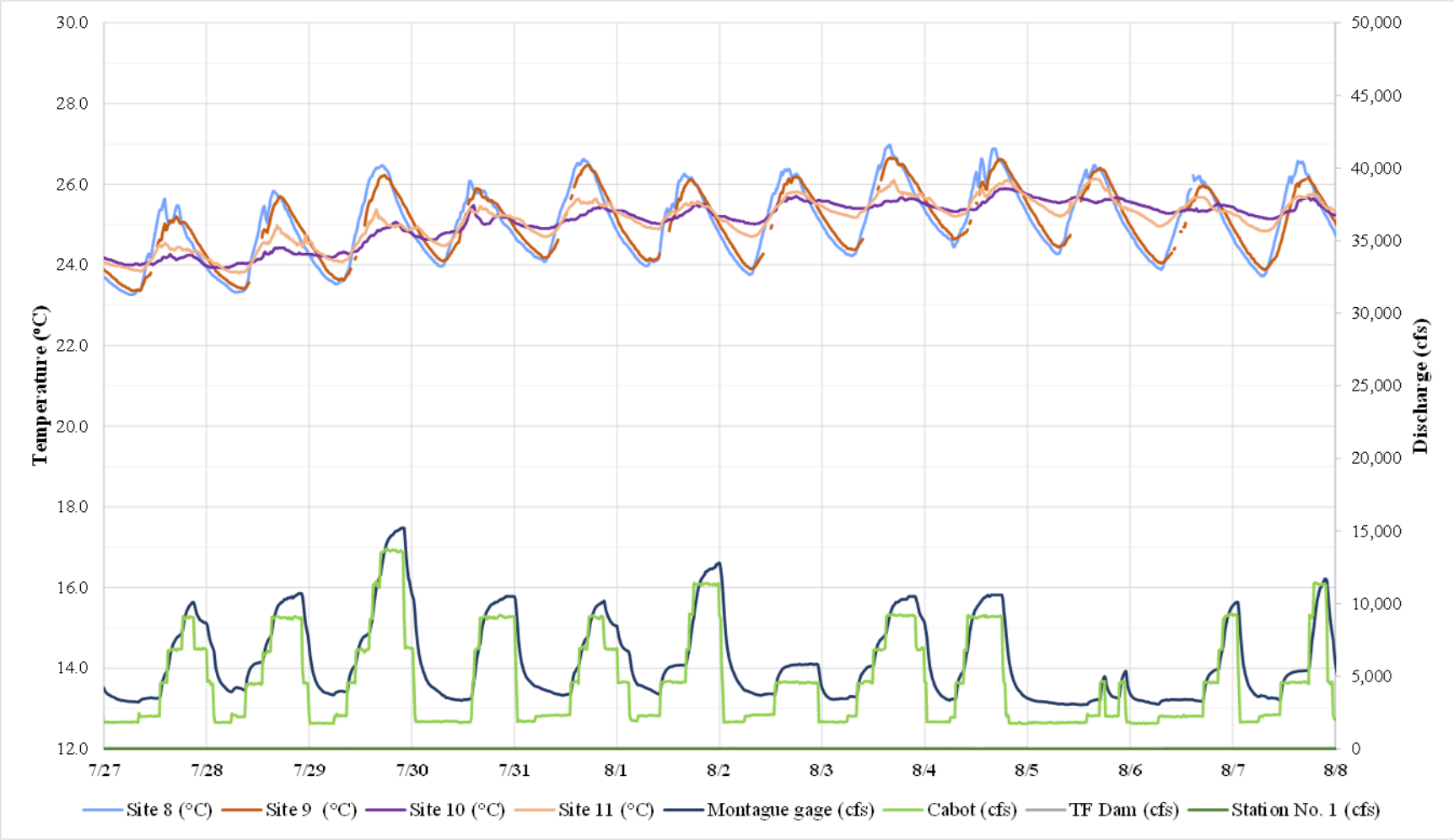


Figure 3.4.4-2c: Water Temperature at Site 11 Downstream of Cabot Station (July 27-August 7, 2015)

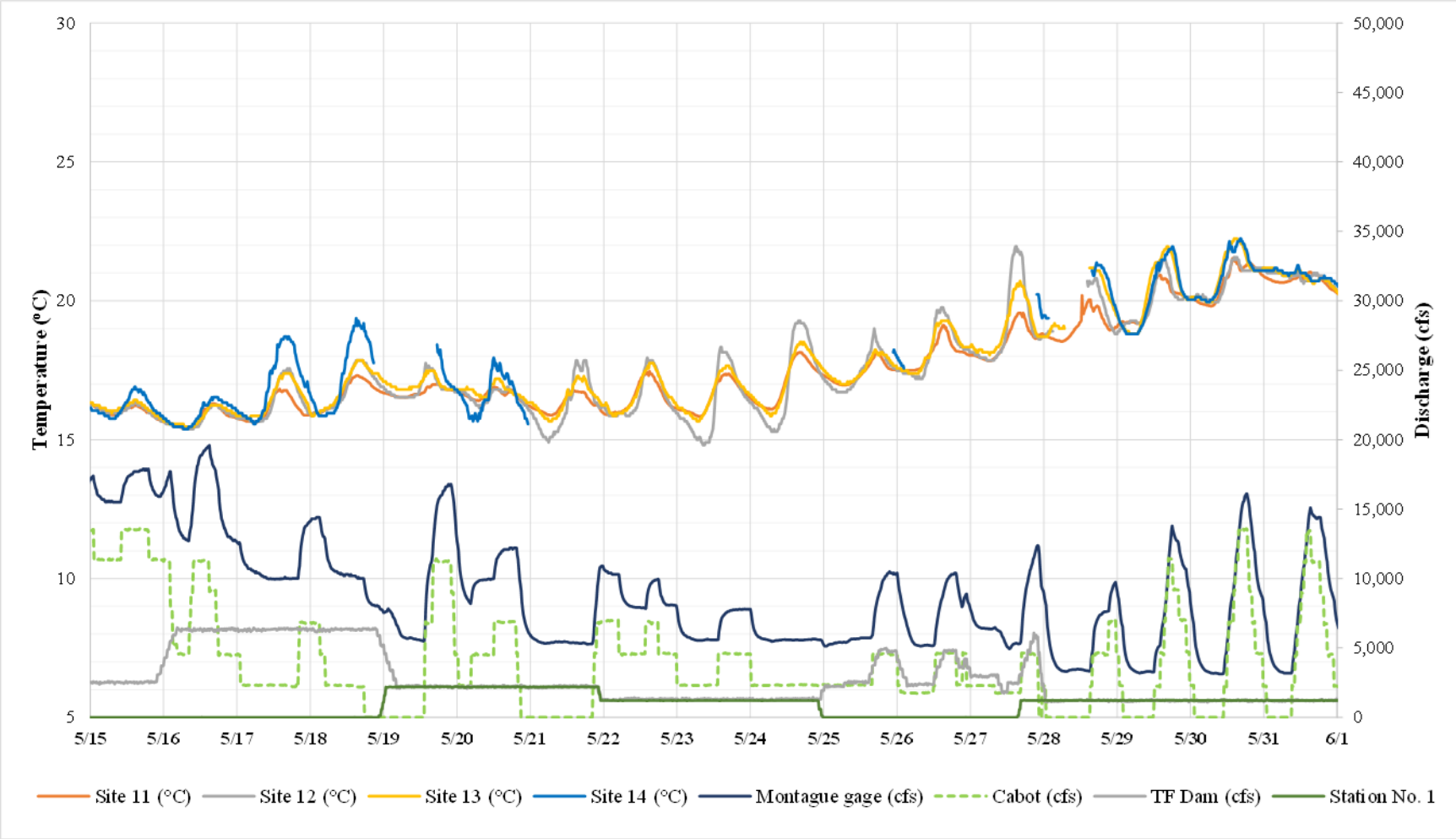


Figure 3.4.5-1: Water Temperature Patterns below Cabot Station (Sites 11-14), May 15-31, 2015

Note: Site 14 data rejected from May 20-28 due to air exposure during low flows.

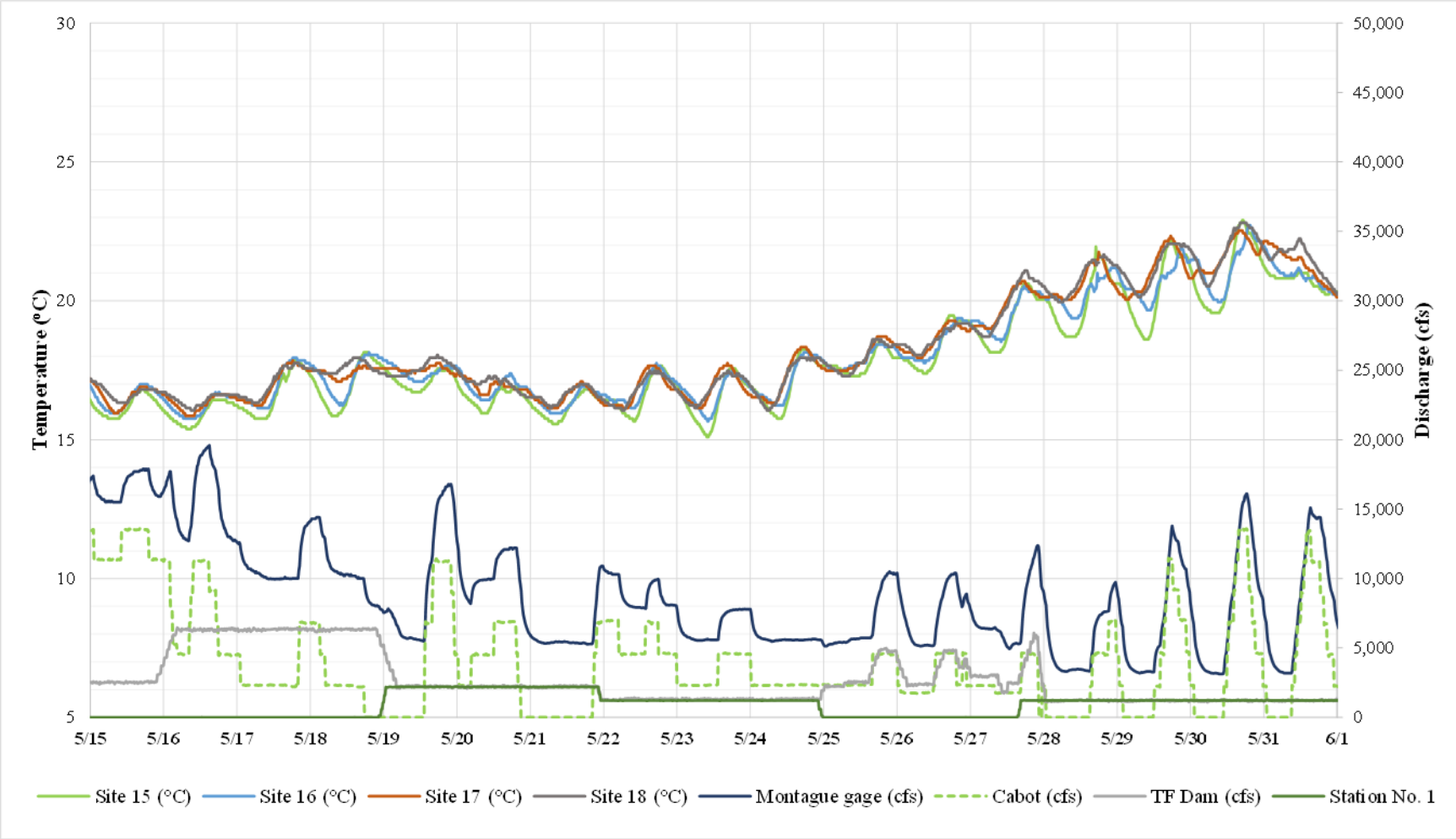


Figure 3.4.5-2: Water Temperature Patterns below Cabot Station (Sites 15-18), May 15-May 31, 2015

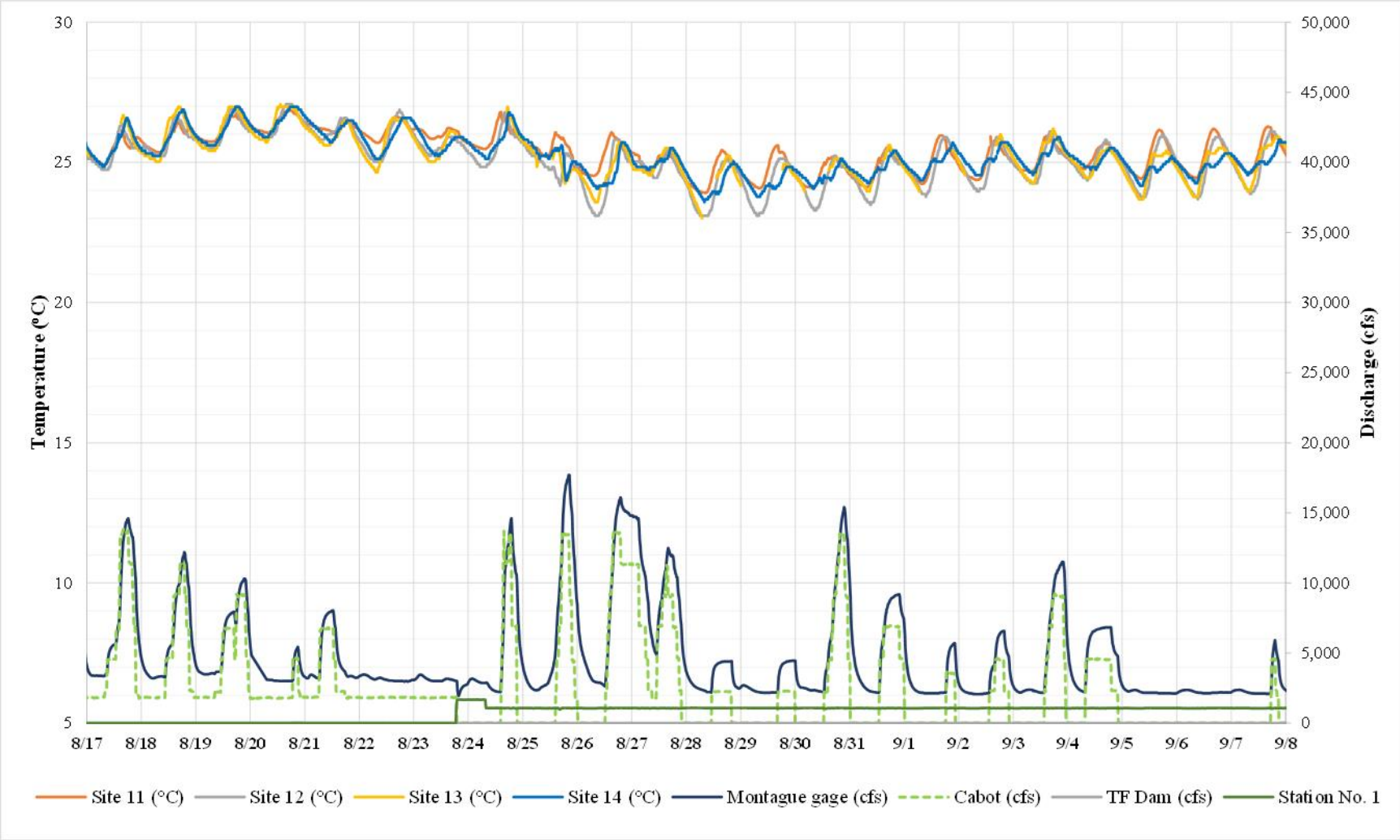


Figure 3.4.5-3: Water Temperature Patterns below Cabot Station (Sites 11-14), August 17-September 7, 2015

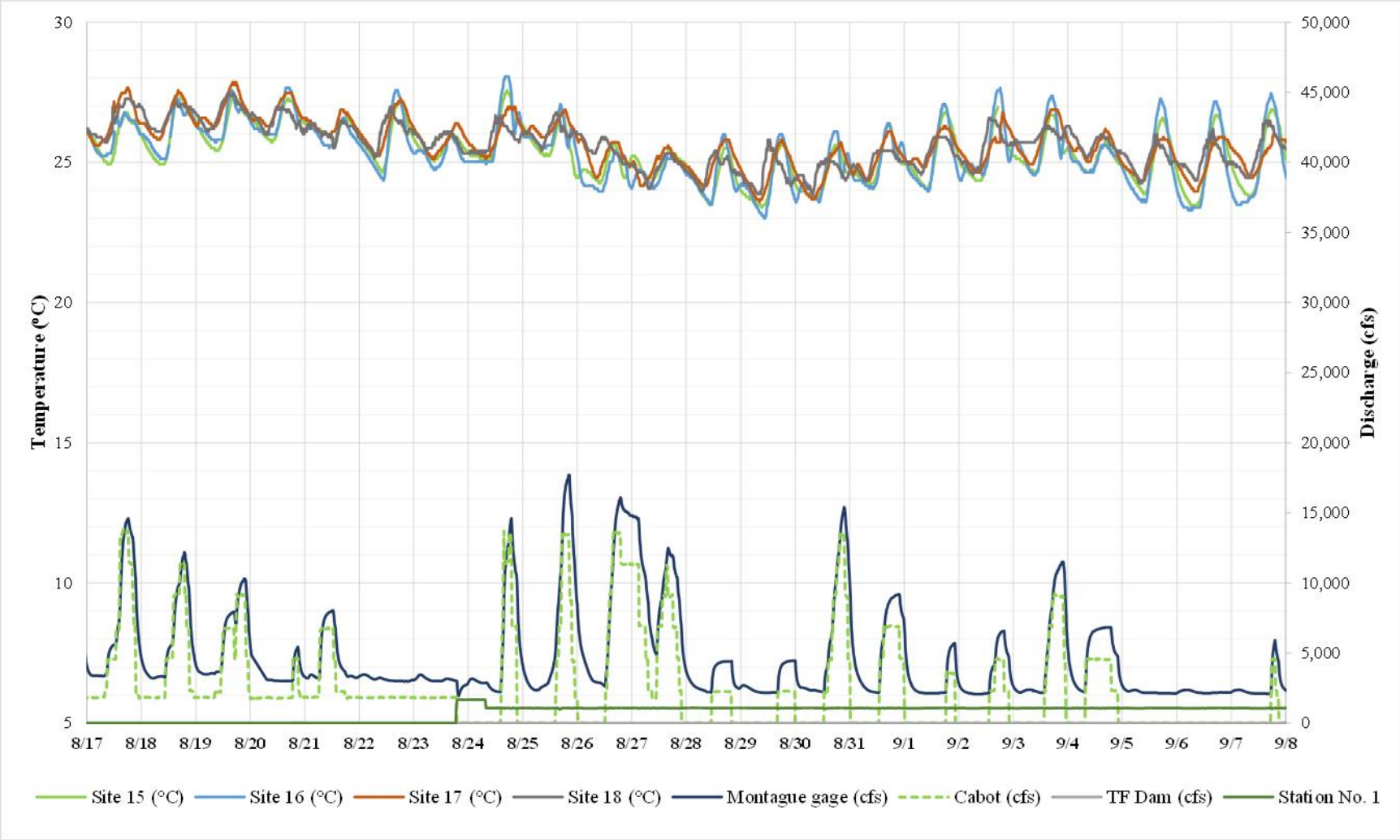
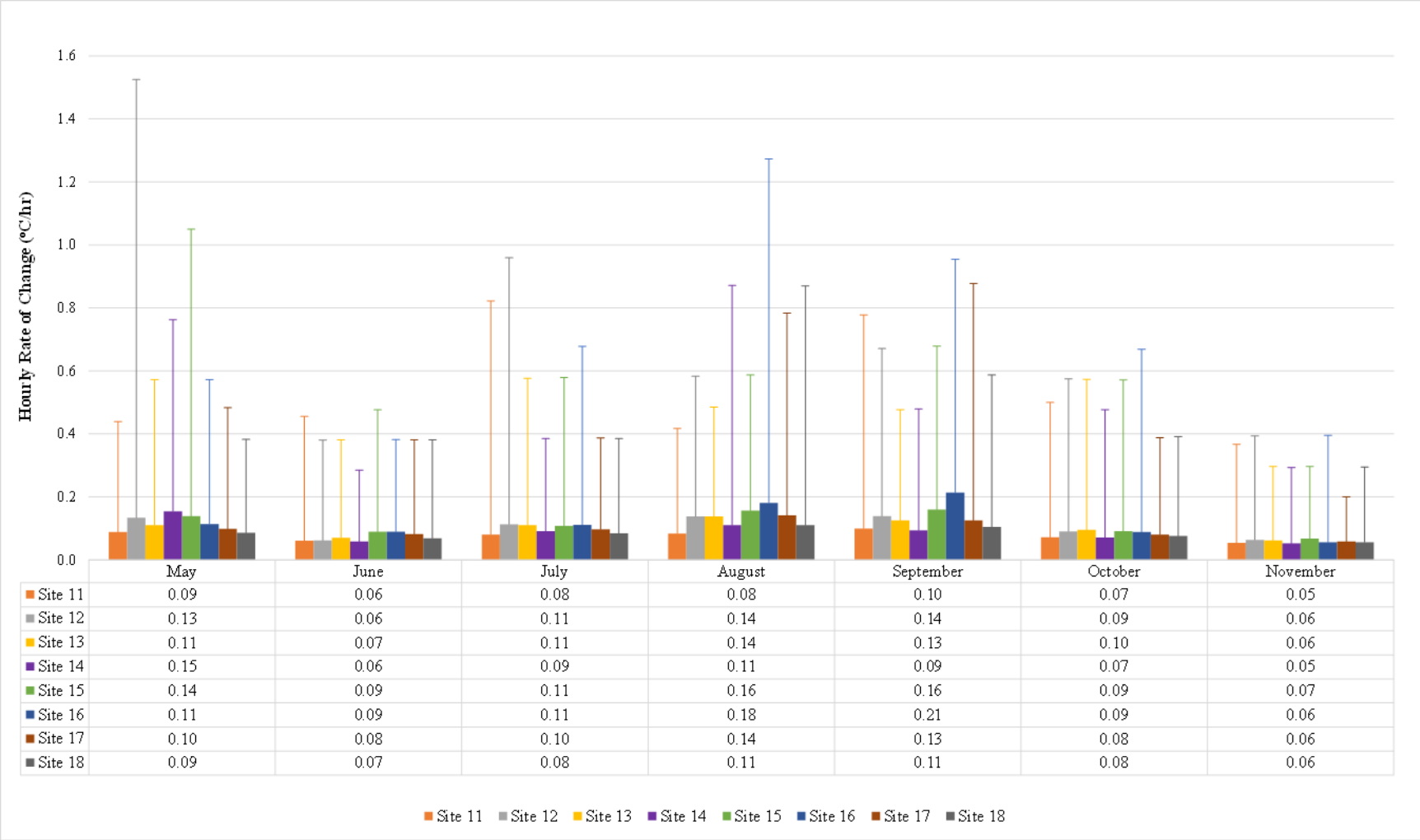


Figure 3.4.5-4: Water Temperature Patterns below Cabot Station (Sites 15-18), August 17-September 7, 2015



	May	June	July	August	September	October	November
Site 11	0.09	0.06	0.08	0.08	0.10	0.07	0.05
Site 12	0.13	0.06	0.11	0.14	0.14	0.09	0.06
Site 13	0.11	0.07	0.11	0.14	0.13	0.10	0.06
Site 14	0.15	0.06	0.09	0.11	0.09	0.07	0.05
Site 15	0.14	0.09	0.11	0.16	0.16	0.09	0.07
Site 16	0.11	0.09	0.11	0.18	0.21	0.09	0.06
Site 17	0.10	0.08	0.10	0.14	0.13	0.08	0.06
Site 18	0.09	0.07	0.08	0.11	0.11	0.08	0.06

Figure 3.4.5-5: Monthly Average and Maximum Temperature Rate of Change (RoC)

Hourly average temperature RoC for each month are represented by bars. Hourly maximum temperature RoC for each month are represented by error bars.

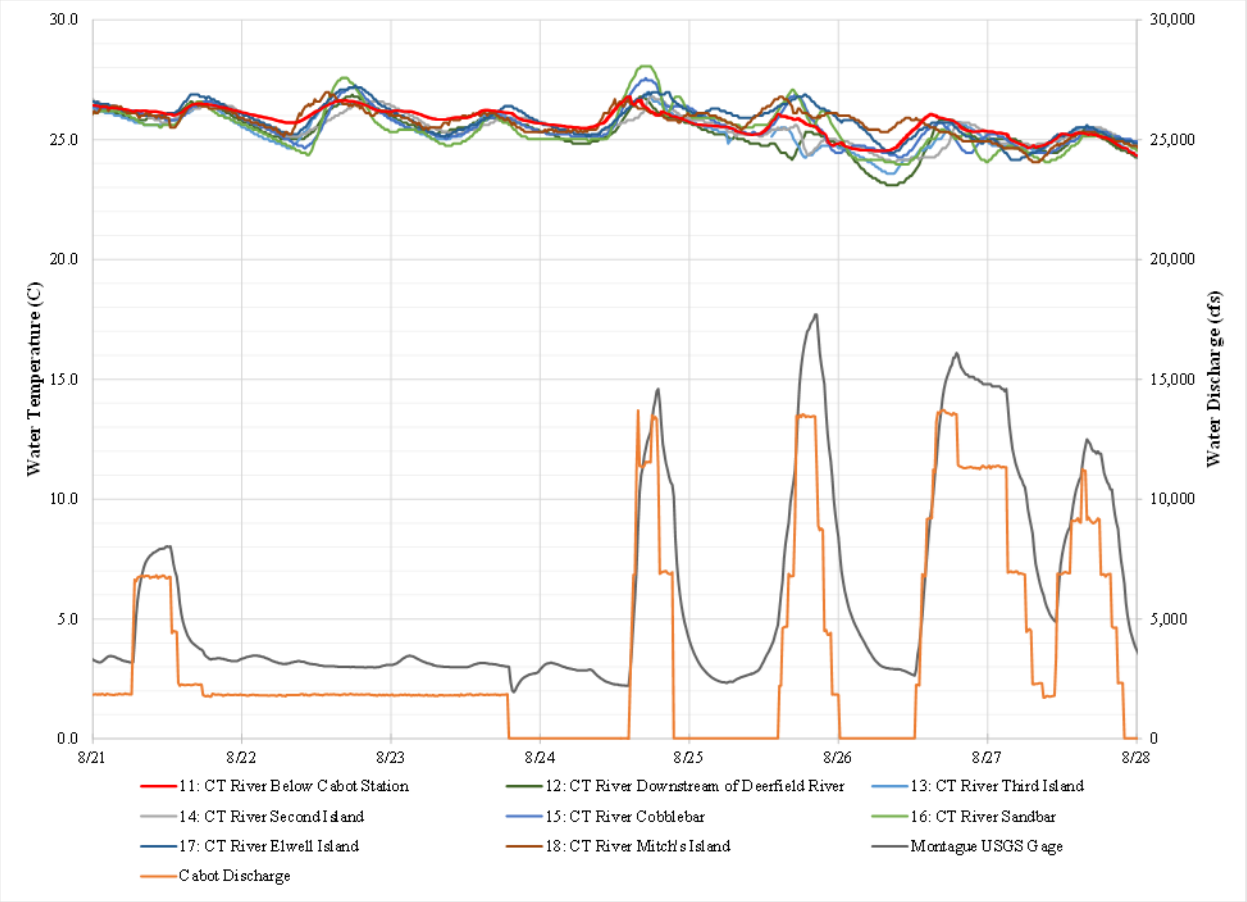


Figure 3.4.5-6a: Water Temperatures at Locations Below Cabot Station Versus Cabot Station Discharge, August 21, 2015 – August 27, 2015

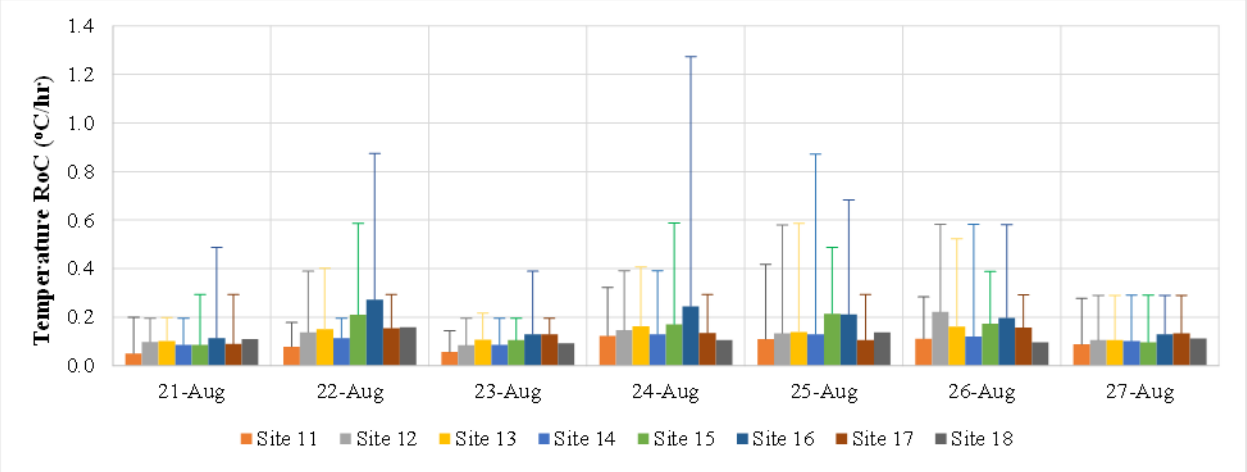


Figure 3.4.5-6b: Hourly Average and Maximum Temperature RoC for August 21, 2015 – August 27, 2015

Hourly average temperature RoCs are represented by bars. Hourly maximum temperature RoCs are represented by error bars.

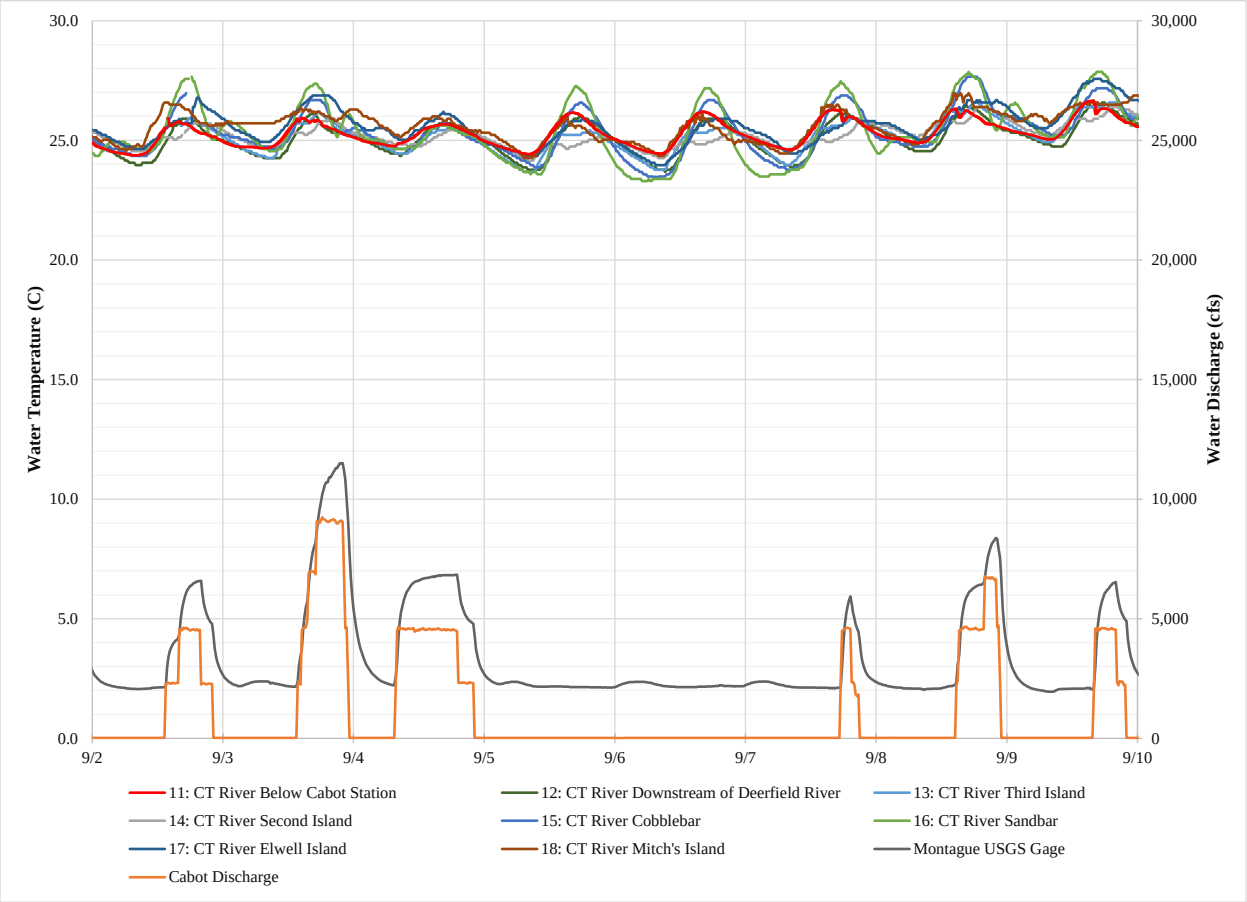


Figure 3.4.5-7a: Water Temperatures at Locations below Cabot Station Versus Cabot Operation Status for September 2, 2015 – September 9, 2015

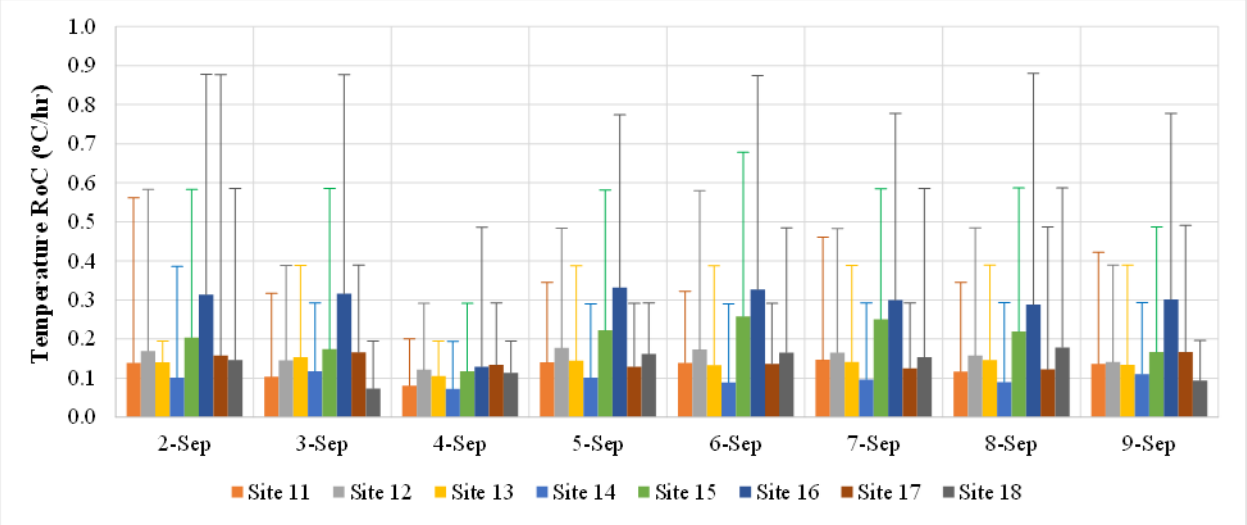


Figure 3.4.5-7b: Hourly Average and Maximum Temperature RoC for September 2, 2015 – September 9, 2015

Hourly average temperature RoCs are represented by bars. Hourly maximum temperature RoCs are represented by error bars.

4 SUMMARY AND CONCLUSIONS

Water quality monitoring was conducted in the study area during spring, summer and fall, 2015. The main purpose of the study was to collect sufficient data to assess and characterize spatial and temporal variations in water quality and to determine compliance with MA water quality standards. Specifically, the objectives of this study were to characterize DO and water temperatures in the Turner Falls Impoundment, bypass reach, power canal and below Cabot Station; to evaluate potential impacts of the Turners Falls Project and Northfield Mountain Project on water temperature and DO; and to characterize water temperature and temperature rate of change in the Connecticut River between Cabot Station and the Holyoke Dam.

The objectives were achieved by collecting biweekly vertical profile data at three locations in the Turners Falls Impoundment and continuous water quality data at sixteen locations throughout the Project and downstream areas. Resulting data were compared against operations, river flow and weather data. The 2015 water quality data were collected over three seasons and captured a range of representative environmental and operational conditions, including low flow, warm temperature conditions in summer. The data led to the following conclusions.

Vertical profile data, collected from the deepest areas of the TFI, indicated that the TFI did not thermally stratify during 2015. DO concentrations and water temperatures were similar from surface to bottom throughout each season of the study period except for a slightly negative DO gradient, surface to bottom, at times.

Throughout the sampling period, all measurements at all sites met state water quality standards. DO values remained above 5 mg/L and water temperatures remained below 28.3°C. Maximum site temperatures ranged from 26.4 °C to 28.1°C for the study period. Monthly average water temperatures were very similar among all locations. August was the warmest month for all locations with an average water temperature of approximately 25°C.

DO and water temperature trends in the TFI generally followed a diurnal pattern in response to solar warming and photosynthesis. DO concentrations and water temperatures were highest during daylight hours and lowest overnight. During periods of generation at the Northfield Mountain Project, subtle, short-term differences in water temperatures and DO were observed at the monitoring sites at and below in the Northfield Mountain Tailrace (i.e., Sites 4 and 5).

Water temperature and DO levels showed a typical diurnal pattern in the bypass reach under minimum flow conditions. Turners Falls Dam spillage and Station No. 1 operations influence DO and temperature in the bypass reach. Spill at Turners Falls Dam generally correlated with higher DO levels as aeration occurs as flow spills over the dam. This spillage is likely to be the major contributing factor to supersaturation in the bypass reach, however, other hydraulic and biological factors may be involved. Regardless, MA WQ standards for DO and temperature were met at the two locations within the bypass reach.

Water temperatures and DO levels in the power canal were similar to conditions at the Turners Falls Dam boat barrier (Site 7) in the TFI. Similarly, water quality conditions just downstream of Cabot Station (Site 11) were similar to conditions in the power canal while Cabot Station was generating.

Water temperature patterns were similar among locations downstream from Cabot Station (Sites 11-18). Monthly average water temperatures were within 1.0°C and typical diurnal patterns were apparent. Some of the sites below Cabot Station were relatively shallow during the summer months, and therefore, the range of diurnal water temperatures was greater than it was at deeper sites. Water temperature daily ranges and hourly rates of change are higher at downstream locations compared to those at Site 11, just downstream of Cabot Station. The maximum hourly rates of change for temperature were between 1.3 and 1.5°C. Average hourly rates of change are typically 0.1 to 0.2 °C at sites below Cabot Station. Water temperature hourly rates of change values are similar regardless of Cabot Station operations during periods of low flow.

5 LITERATURE CITED

FirstLight. (2015). Health and Safety Plan (Rev 3) for FERC Licensing Studies. Northfield Mountain Pumped Storage Project (No. 2485) and Turners Falls Hydroelectric Project (No. 1889). Author.

Massachusetts Department of Environmental Protection (MADEP). (2007). Standard Operation Procedure: Multi-Probe Sonde Deployments for Continuous Unattended Water Quality Data Collection. Massachusetts Department of Environmental Protection, Division of Watershed Management. June 2007. CN 4.41. 17 pp.

Massachusetts Department of Environmental Protection (MADEP). (2009). Standard Operation Procedure: Continuous Temperature Monitoring using Temperature-only Loggers. Massachusetts Department of Environmental Protection, Division of Watershed Management. May 2009. CN 103.1. 19 pp.

Massachusetts Department of Environmental Protection (MADEP). (2013). 314 CMR 4.0: Massachusetts Surface Water Quality Standards. Massachusetts Department of Environmental Protect, Division of Water Pollution Control. December 2013. Retrieved March 12, 2014 from http://www.mass.gov/eea/docs/dep/service/regulations/314cmr04.pdf.

Wetzel, R. G. (2001). Limnology: Lake and River Ecosystems (3rd ed.). San Diego, CA: Academic Press.

APPENDIX A – FIELD SAMPLING PLAN

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

RELICENSING STUDY 3.2.1

WATER QUALITY MONITORING STUDY

FIELD SAMPLING PLAN

Filed with Initial Study Report - September 2014
[Appendices Removed from This Version]

Table of Contents

List of Tables

List of Figures

Appendices

1.0 Introduction

FirstLight Hydro Generating Company (FirstLight) initiated the relicensing of its 1,119.2 MW Northfield Mountain Pumped Storage Project (FERC No. 2485) and 67.09 MW Turners Falls Hydroelectric Project (FERC No. 1889) with the Federal Energy Regulatory Commission (FERC or Commission). The Projects are located on the Connecticut River in the towns of Northfield, MA (River Mile (RM) 127.2) and Turners Falls, MA (RM 122), respectively.

In accordance with the relicensing process, multiple stakeholders requested FirstLight to conduct a water quality monitoring study to determine the effect of Project operations on water quality of the Connecticut River within the Turners Falls Impoundment (Impoundment), bypass reach, power canal, and the Cabot Station tailrace reach. FirstLight filed a Revised Study Plan (RSP) on August 14, 2013 with FERC. Study 3.2.1 contained the plan for conducting the Water Quality Monitoring Study.

FERC issued its Study Plan Determination Letter (SPDL) for the aquatic studies on February 21, 2014, approving the Water Quality Monitoring Study Plan with certain modifications. The primary modification required that FirstLight develop a study plan component for temperature monitoring of the Connecticut River between Cabot Station and the Holyoke Dam to describe temperature and temperature rate of change associated with peaking operations.

Task 1 of the RSP requires that FirstLight develop a sampling plan in consultation with interested stakeholders prior to sampling. The methods described in this plan were developed based on the FERC-approved RSP, as modified, and standard operating procedures provided by the Massachusetts Department of Environmental Protection (MADEP) which are included in Appendix A to this plan.

2.0 Study Goals and Objectives

The purpose of this field sampling plan is to provide a detailed description of the water quality and temperature monitoring protocols, procedures, data quality control, and reporting that will be conducted. The results of this study will provide information sufficient to enable agencies and stakeholders to understand water quality conditions and dynamics within the Project area and downstream to the Holyoke Dam.

The specific objectives of the study are to:

- Characterize water temperature and dissolved oxygen (DO) conditions within the Turners Falls Impoundment, bypass channel, power canal, and below Cabot Station;
- Determine potential impacts of the Turners Falls Project and Northfield Mountain Project on water temperature and DO;
- Compare collected data with applicable State water quality standards;
- Describe water temperature and temperature rate of change between Cabot Station and the Holyoke Dam.

3.0 Study Locations

The RSP contained 11 sampling stations from below Vernon Dam to downstream of Cabot Station. Seven additional temperature monitoring locations from below Cabot Station downstream to the Holyoke

Dam have been added to this plan for a total of 18 sampling locations (Table 3.1). Continuous temperature and DO will be measured and recorded at nine locations within the project area, listed below and shown in Figure 3.1, Figure 3.2 and Figure 3.3.

- Below the Vernon Dam and Ashuelot River confluence
- Above the Northfield Mountain tailrace
- Northfield Mountain tailrace
- Below the Northfield Mountain tailrace
- Upstream of the Turners Falls Dam at boat barrier
- Bypass reach upstream of Station No. 1
- Bypass reach upstream of Rock Dam
- Turners Falls Power Canal
- Below Cabot Station tailrace

DO and temperature profiles will be collected at three relatively deep locations within the Impoundment (Figure 3.4), listed below.

- Upstream of the Turners Falls Dam at boat barrier (same location at continuous monitoring site)
- Approximately 3.0 mi upstream of the Turners Falls Dam, at the deepest known area within the impoundment.
- Approximately 4 miles upstream of the MA Route 10 Bridge.

In addition, continuous temperature data will be collected at seven locations downstream of Cabot Station to the Holyoke Dam (Figure 3.5). The locations were selected with input from the Connecticut River Watershed Council (CRWC) and MA Natural Heritage and Endangered Species Program (NHESP). The proposed locations of the temperature monitoring stations are listed below.

- Downstream of the Deerfield River confluence
- Second Island, Sunderland, MA
- Third Island, Sunderland, MA
- Sandbar above Mill River, Hadley, MA
- Sandbar below Mill River, Hadley, MA
- Side channel at Elwell Island, Hadley, MA

- Near Mitch's Island, Hadley, MA

4.0 Methodology for Continuous Dissolved Oxygen and Temperature Data Collection

Equipment

Continuous temperature and DO monitoring will be conducted using HOBO DO Loggers (Model U26-001), which also records temperature. The HOBO DO Loggers are ideal for long-term deployment (>10 days) because it is equipped with an optical sensor to measure DO, which is more resistant to biofouling than membrane sensors, and can last up to six-months after initialization. The logger has an operating temperature and DO range of -5 to 40°C and 0 to 30 mg/L, respectively. Specifications for the sampling equipment proposed for this study are provided in Table 4.1.

In order to collect DO as percent saturation (in addition to mg/L) the HOBO loggers require barometric pressure (BP) data. BP data will be continuously collected over the course of the study using a HOBO Water Level Logger (Model U20-001-04) as recommended by the manufacturer. Onset documentation specifies that the loggers operate between a pressure range of 0 to 145 kPa (0 to 21 psia) with a raw pressure accuracy of 0.3%. The BP sensor will be installed in the air in a secure location in the vicinity of the sampling sites for the study duration.

Calibration

The HOBO DO Loggers will be calibrated prior to deployment using the Lab Calibration tool found in the manufacturer's software. The loggers will need to be calibrated before deployment or after replacing an expired sensor cap. Sensor caps expire approximately 7 months after initialization. The Lab Calibration tool sets the gain and offset adjustment for the logger by: 1) restoring logger calibration values to factory defaults; 2) using your own gain and offset adjustment values; or 3) calculating the values with a three-step calibration procedure. If the three-step calibration procedure is chosen, the logger is first calibrated to 100% saturation by placing it in water-saturated air. Following this, the logger is then calibrated to 0% saturation by placing it in sodium sulfite or another 0% oxygen environment. The manufacturer recommends 0% saturation calibration only if the logger will be deployed in waters with possible DO levels ≤ 4 mg/L. These loggers will be tested in a common bath before deployment to ensure they are collecting data and similar measurements (MADEP, 2009). All pre-deployment calibrations will be performed in the laboratory (MADEP, 2007). In addition, a hand-held thermometer traceable to a NIST-certified thermometer will be used to check sensor accuracy; checks will be made prior to deployment, monthly, and at retrieval.

It may be necessary, and recommended by the manufacturer (Onset® Computer Corporation), to take DO field calibration readings if biofouling is present or likely to occur. Field calibration readings will be conducted following the manufacturers recommendations, which include: using another calibrated DO meter to obtain replicate DO measurements, downloading data from the logger, cleaning the sensor, and taking another field calibration reading. The DO readings will then be corrected using the field calibration readings and the manufacturer's software, HOBO DO Assistant, which compensates for any measurement drift due to biofouling *(i.e.*, correction of the DO measurements occurs *post hoc)*.

Field Sampling Specifications

Temperature (°C) and DO (mg/L) will be recorded *in situ* every 15 minutes at the nine locations identified above. Water temperature at the nine locations will be recorded from April 1 through November 15, while DO will be recorded during the summer low-flow, high temperature period from June 1 through September 30. Deployment of the continuous temperature and DO data loggers will generally follow

procedures employed by the MADEP, Division of Watershed Management Standard Operating Procedure of Multiprobe Deployment (MADEP, 2007).

Five of the nine locations will be in the Impoundment (Figure 3.1). Each of these data loggers will be deployed in a representative location at a minimum of 4 ft from the surface, but not deeper than 25% depth. To confirm representativeness, periodic measurements of surface, logger depth and near bottom will occur.

The remaining continuous temperature and DO data loggers will be deployed in the bypass reach, power canal, and below Cabot Station (Figure 3.2). Loggers at these locations will be placed in a representative location in mid-channel or thalweg at mid-depth, or just off the bottom depending on site-specific characteristics. Installation locations will be selected that are low risk for vandalism and will be as unobtrusive as possible to minimize conflicts with recreational use of the river. Areas of low water velocities (~< 1 fps) and significant turbulence will be avoided to the extent possible (MADEP, 2007). All loggers will be encased in perforated pipe, and attached to an immovable object or anchor using polypropylene rope or cable (MADEP, 2009).

Bi-weekly site visits (i.e., once every two weeks) will occur to periodically inspect the loggers for biofouling, download data, and obtain replicate temperature and DO measurements for quality assurance/quality control (QA/QC) purposes. Data will be downloaded from the loggers on a bi-weekly basis to assure the logger is functioning correctly over the long deployment duration. GPS coordinates and photo documentation will be obtained of each location; and weather, river flow, and condition of the logger and battery life will be recorded in a field notebook during deployment, bi-weekly sampling, and retrieval.

5.0 Methodology for Dissolved Oxygen and Temperature Profile Data Collection

Equipment

The temperature and DO profiles will be collected using a portable handheld YSI ProODO meter equipped with a 50 m cable. The meter provides temperature (°C), DO (mg/L; % saturation), and BP (mmHg) readings. The YSI ProODO meter has an operating range of -5 to 70°C and 0 to 50 mg/L. Additional specifications for the YSI ProODO meter are provided in Table 4.1.

Calibration

A one-point calibration (water saturated air) will be conducted at the beginning (prior to sampling) and end (following all sampling) of each sample day. Calibration will follow the instructions described in the YSI ProODO manual. Calibration results will be saved on the logger and recorded on the applicable field data sheet (Appendix B). In addition, a hand-held thermometer traceable to a NIST-certified thermometer will be used to check sensor accuracy; checks will be made prior to deployment, monthly, and at retrieval.

Field Sampling Specifications

Temperature (°C) and DO (mg/L; % saturation) profiles will be collected on a bi-weekly basis at the locations described above to characterize the temperature and DO profile and timing of stratification within the Impoundment. The bi-weekly sampling will be conducted concurrently with the other water quality monitoring beginning April 1 through November 15, 2015. Profile sampling will generally follow procedures employed by the MADEP, Division of Watershed Management Standard Operating Procedure for Lake Sampling (MADEP, 2010) and Water Quality Multiprobe Data Collection (MADEP, 2005).

Vertical profile sampling will occur at a consistent time across sampling events and as early in the morning as possible. GPS coordinates and photo documentation will be obtained of each location.

Prior to taking the temperature and DO profile, the boat will be anchored with the bow facing upwind or upstream. When the boat becomes stabilized a portable depth sounder will be used to obtain a depth measurement. Starting at the surface, measurements of temperature and DO will be collected at 1.0 m depth increments[1]; the last measurement will be 0.5 m above bottom, but only if the primary user is certain the probe did not make contact with the bottom (MADEP, 2005). Measurements will only be recorded after waiting at least 30 seconds at each depth interval to allow the instrument to stabilize. Only after the instrument is stabilized will a reading be recorded and the probe lowered to the next interval. At least one replicate measurement at a random depth interval will also be measured. All data along with the approximate locations of the strata (epi-, meta-, and hypolimnia) and depth of the thermocline will be recorded on the field data sheets (MADEP, 2005). An example field data sheet is provided in Appendix B.

Replicate measurements will also be collected at least once per vertical profile, or after every twentieth measurement at a random depth interval. If the profile appears to be stratified, replicate measurements within the metalimnion (thermocline) will be avoided because temperature and DO gradients can express subtle changes in relation to depth in this layer of the impoundment. All replicate measurements will be recorded manually.

6.0 Methodology for Continuous Temperature Data Collection

Equipment

Continuous temperature data collected from Cabot Station to the Holyoke Dam will be collected using HOBO Water Temperature Pro v2 Data Loggers (Model U22-001). This logger has an operating range of -40 to 70°C. Specifications for the HOBO Water Temperature Pro v 2 Data Loggers are provided in Table 4.1.

Calibration

The HOBO Water Temperature Pro v2 Data Loggers (Model U22-001) are factory calibrated; therefore, no calibration is necessary. However, the loggers will be tested in a common bath prior to deployment to ensure they are functioning properly and that their measurements are similar (within± 0.5°C) (MADEP, 2009). In addition, a hand-held thermometer traceable to a NIST-certified thermometer will be used to check sensor accuracy; checks will be made prior to deployment, monthly, and at retrieval.

Field Sampling Specifications

Water temperature (°C) of the Connecticut River will be continuously monitored *in situ* every 15-minutes at five locations from Cabot Station to the Holyoke Dam from April 1 through November 15. Deployment of the continuous temperature loggers will generally follow procedures employed by the MADEP, Division of Watershed Management Standard Operating Procedure of Continuous Temperature Monitoring using Temperature-only Loggers (MADEP, 2009).

Each logger will be deployed at a representative location, and at a sufficient distance downstream of the mixing zone of any significant tributaries of the Connecticut River, such as the Deerfield and Fort Rivers.

[1] Because Station No. 6 is extremely deep, the vertical profile measurement intervals will be collected every 1.0 meter starting at the surface, until a homothermous condition is encountered in the hypolimnion.

The loggers will be encased in perforated protective housing, and secured off the bottom of the river with rocks or concrete blocks. The logger assembly will be tethered to an immovable object on shore with polypropylene rope or cable.

Periodic site visits will occur to inspect the meters, download data, and obtain replicate temperature measurements for QA/QC purposes. Replicate measurements will be collected adjacent to each continuous data logger during each site visit using a separate meter. Data will be downloaded from the loggers to assure the logger is functioning correctly over the long deployment duration. GPS coordinates and photo documentation will be obtained of each location; and the condition of the logger will be recorded in a field notebook during each site visit.

7.0 Data Management and Reporting

7.1 Data Management

All temperature and DO measurements collected at the three, vertical profiles will be recorded in a field notebook or on field data sheets on the day of sampling. Data will include DO and water temperature measurements, general weather and flow conditions, and QA/QC data records. Continuous temperature and DO data collected using the HOBO data loggers will be stored on the logger's memory and downloaded during each bi-weekly sampling event, and again at the end of the study period. Hourly operations data regarding the Impoundment elevation, periods of pumping, generating, or idle, discharge over Turners Falls Dam, and natural routed flow will be provided by FirstLight.

7.2 Data Review

All field-collected data will undergo a thorough QA/QC review process to ensure accuracy and completeness of the dataset. Adherence to standard methods and QA/QC procedures for all water quality monitoring helps ensure that the resulting data will be accurate, precise, comparable, and representative.

Data will be reviewed at the end of each day (vertical profiles) or periodically throughout (continuous data) the course of the study. All continuous water quality data will be analyzed for outliers or other aberrant data points. DO data collected from the continuous loggers will be corrected, as necessary, using the field calibration/replicate DO readings. The HOBOware DO Assistant corrects the DO values as a result from measurement drift due to biofouling. This correction process will only be performed if biofouling on the logger is believed to compromise the measurements or the readings from the loggers are not within the measurement error of the replicate data.

7.3 Reporting

At the conclusion of the study and following QA/QC of the data, results and findings will be summarized in a final report. The final report will be submitted to FERC as part of the Integrated Licensing Process (ILP) schedule. All water quality data collected as part of this study will be submitted to the regulatory agencies in an electronic format that can be automatically uploaded to their respective databases.

8.0 Schedule and Consultation

Per FERC's SPDL for the aquatic studies, this plan is to be developed in consultation with interested stakeholders and specific approval is required from MADEP, USFWS and NHDES. A draft of this plan was submitted to interested stakeholders on June 27, 2014. Comments were received from MADEP, CRWC, and the MA NHESP.

This sampling plan has been revised to address the comments received. Table 1 in Appendix C provides a summary of how the comments were addressed. Copies of the comment letters received are included in Appendix C.

Once the plan is approved by FERC, the field study will be implemented between April and November 2015.

Continuous DO data will be collected during the summer low-flow, high temperature period starting on June 1 (continuous temperature data collection will commence on April 1). As requested by MADEP, data through June 30 will be provided to MADEP along with the corresponding vertical profile data. FirstLight will then consult with MADEP to determine if early morning vertical profile collection is justified. If so, FirstLight will adjust the time of data collection, as directed by MADEP and as impoundment travel time constraints and safety considerations allow for.

9.0 Literature Cited

Massachusetts Department of Environmental Protection (MADEP). 2013. 314 CMR 4.0: Massachusetts Surface Water Quality Standards. Massachusetts Department of Environmental Protect, Division of Water Pollution Control. December 2013. < http://www.mass.gov/eea/docs/dep/service/regulations/314cmr04.pdf>. Accessed March 12, 2014.

Massachusetts Department of Environmental Protection (MADEP). 2010. Standard Operation Procedure: Lake Sampling. Massachusetts Department of Environmental Protection, Division of Watershed Management. January 2010. CN 151.0. 21 pp.

Massachusetts Department of Environmental Protection (MADEP). 2009. Standard Operation Procedure: Continuous Temperature Monitoring using Temperature-only Loggers. Massachusetts Department of Environmental Protection, Division of Watershed Management. May 2009. CN 103.1. 19 pp.

Massachusetts Department of Environmental Protection (MADEP). 2007. Standard Operation Procedure: Multi-Probe Sonde Deployments for Continuous Unattended Water Quality Data Collection. Massachusetts Department of Environmental Protection, Division of Watershed Management. June 2007. CN 4.41. 17 pp.

Massachusetts Department of Environmental Protection (MADEP). 2005. Standard Operation Procedure: Water Quality Multiprobe Data Collection. Massachusetts Department of Environmental Protection, Division of Watershed Management. September 2005. CN 4.21. 46 pp.

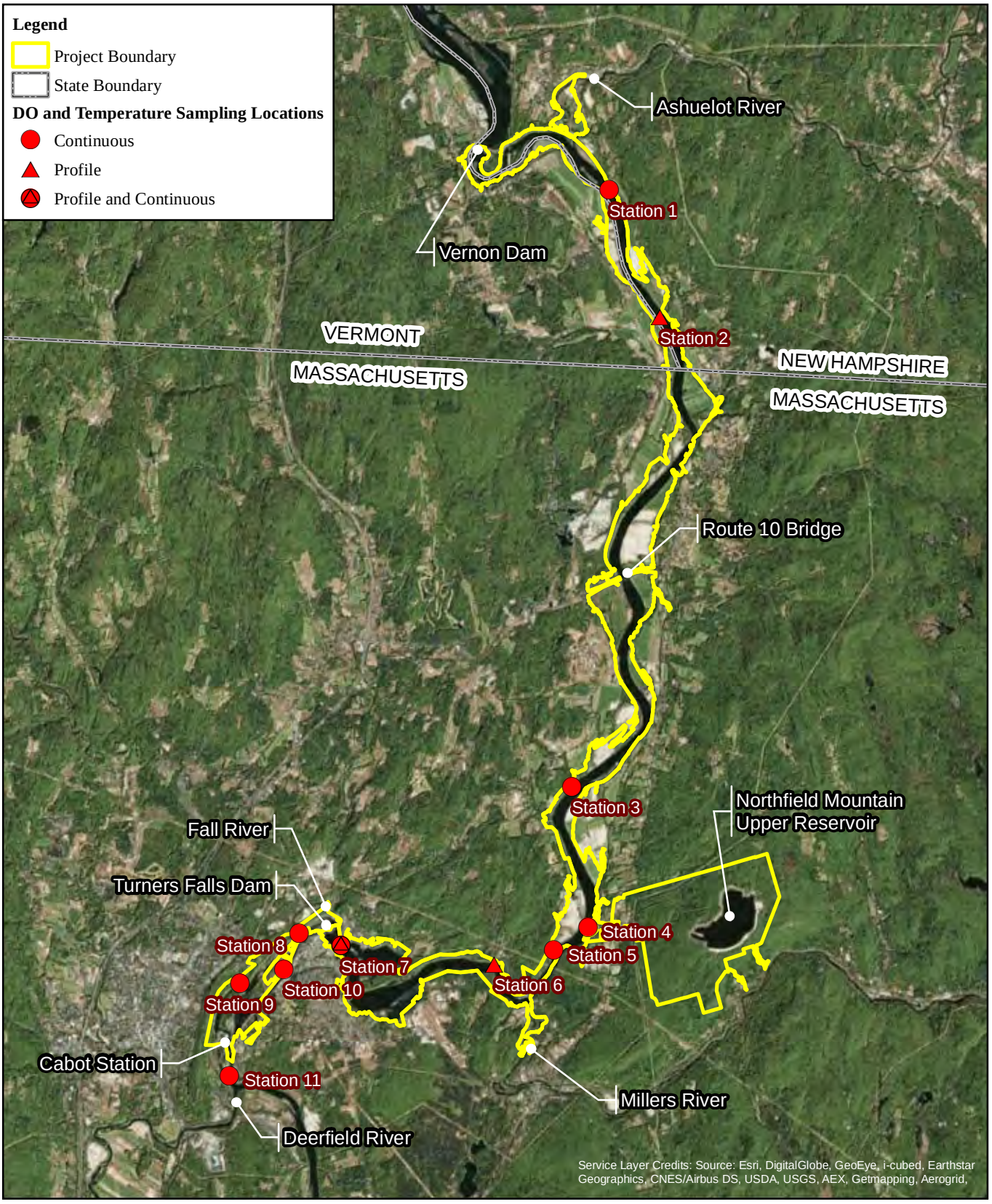
United States Geological Survey (USGS). 2006. Guidelines and Standard Procedures for Continuous Water-quality Monitors: Station Operation, Record Computation, and Data Reporting. Techniques and Methods Report: 1-D3. 96 pp.

Table 3.1: Water Quality Monitoring Sampling Locations.

Station No.	Type	Location	Comments
Connecticut River- Turners Falls Impoundment (Temperature and DO)			
1	Continuous	Below the Vernon Dam and Ashuelot River Confluence	Near thalweg at 25% depth
2	Profile	Deep area upstream of Northfield Mountain	Collect profile at one meter depth increments
3	Continuous	Above the Northfield Mountain Discharge; Downstream of Kidds Island	Near thalweg at 25% depth
4	Continuous	Northfield Mountain Tailrace	Within the Northfield Mountain Tailrace at 25% depth
5	Continuous	Below the Northfield Mountain Tailrace; Upstream of Millers River Confluence	Near thalweg at 25% depth
6	Profile	Deepest area of Turners Falls Impoundment	Collect profile at one meter depth increments until homothermous hypolimnion is encountered
7	Profile and Continuous	Upstream of the Turners Falls Dam at Boat Barrier	Collect profile at one meter depth increments and install continuous meter at 25% depth
Connecticut River- Bypass Reach (Temperature and DO)			
8	Continuous	Upstream of Station No. 1	Mid-channel, mid-depth
9	Continuous	Upstream of Rock Dam; west channel at Rawson Island.	Mid-channel, mid-depth
Turners Falls Power Canal (Temperature and DO)			
10	Continuous	At the 11th Street Bridge	Mid-channel, mid-depth
Connecticut River- Below Cabot Station (Temperature and DO)			
11	Continuous	Below the Cabot Station tailrace, upstream of Deerfield River confluence	Thalweg, mid-depth.
Connecticut River- Cabot Station to Holyoke Dam (Temperature)			
12	Continuous	Downstream of the Deerfield River confluence	Anchored near bottom, near shore
13	Continuous	Third Island	Anchored near bottom, near shore of island
14	Continuous	Second Island, near shore of island.	Anchored near bottom, near shore of island
15	Continuous	Submerged shallow sandbar	Anchored near bottom, at sandbar
16	Continuous	Submerged shallow sandbar	Anchored near bottom, at sandbar
17	Continuous	River right channel at Elwell Island	Anchored near bottom, near shore
18	Continuous	Upstream of Mt. Tom Station, near Mitch's Island	Anchored near bottom, near shore

Table 4.1: Water Quality Monitoring Instrument Specifications.

Parameter	Specification	Description
HOBO® Dissolved Oxygen Logger (U26-001)		
Dissolved Oxygen (mg/L)	Sensor type	Optical (dynamic luminescence quenching)
	Operating Range	0 to 30 mg/L
	Calibrated Range	0 to 20 mg/L (0 to 35°C)
	Accuracy	0.2 mg/L up to 8 mg/L; 0.5 mg/L from 8 to 20 mg/L
	Resolution	0.02 mg/L
	Sensor Life	6 months
Temperature (°C)	Operating Range	-5 to 40°C
	Accuracy	0.2°C
	Resolution	0.02°C
Depth Rating	—	100 m
Battery Life	—	3 years at 5-minute logging intervals
YSI ProODO		
Dissolved Oxygen (mg/L)	Sensor type	Optical (dynamic luminescence quenching)
	Range	0 to 50 mg/L
	Accuracy	± 0.1 mg/L (0 to 20 mg/L) or 1% of reading; ± 10% of reading (20 to 50 mg/L)
	Resolution	0.01 or 0.1 mg/L (autoscaling)
Dissolved Oxygen (% saturation)	Sensor type	Optical (dynamic luminescence quenching)
	Range	0 to 500% air saturation
	Accuracy	±1% 1% of reading (0 to 200% air saturation) or ± 10% (200 to 500% air saturation)
	Resolution	0.1% air saturation
Temperature (°C)	Range	-5 to 70°C
	Accuracy	±0.2°C
	Resolution	0.1°C
Barometer (mmHg)	Range	375 to 825 mmHg
	Accuracy	±1.5 mmHg (0 to 50°C)
	Resolution	0.1 mmHg
Cable Length	—	50 m
HOBO® Water Temp Pro v2 (U22-001)		
Temperature (°C)	Range	-40 to 70°C in air; 50°C maximum in water
	Accuracy	±0.21°C (o to 50°C)
	Resolution	0.02°C at 25°C
Battery Life	—	6 years at 1-minute logging intervals
Depth Rating	—	120 m



FirstLight
GDF SUEZ

N

FIRSTLIGHT POWER RESOURCES

RELICENSING STUDY 3.2.1
WATER QUALITY MONITORING
FIELD SAMPLING PLAN

0 0.75 1.5 3 Miles

Figure 3.1:
Overview of DO and Water Temperature Sampling Locations

Path: W:\gis\studies\3_2_1\maps\Figure 3.1.mxd

FirstLight
GDF SUEZ

N

FIRSTLIGHT POWER RESOURCES

RELICENSING STUDY 3.2.1
WATER QUALITY MONITORING
FIELD SAMPLING PLAN

0 0.25 0.5 1 Miles

Figure 3.2:
Water Quality Sampling
Locations Near Turners Falls Dam

Path: W:\gis\studies\3_2_1\maps\Figure 3.2.mxd

FirstLight GDF SUEZ

N

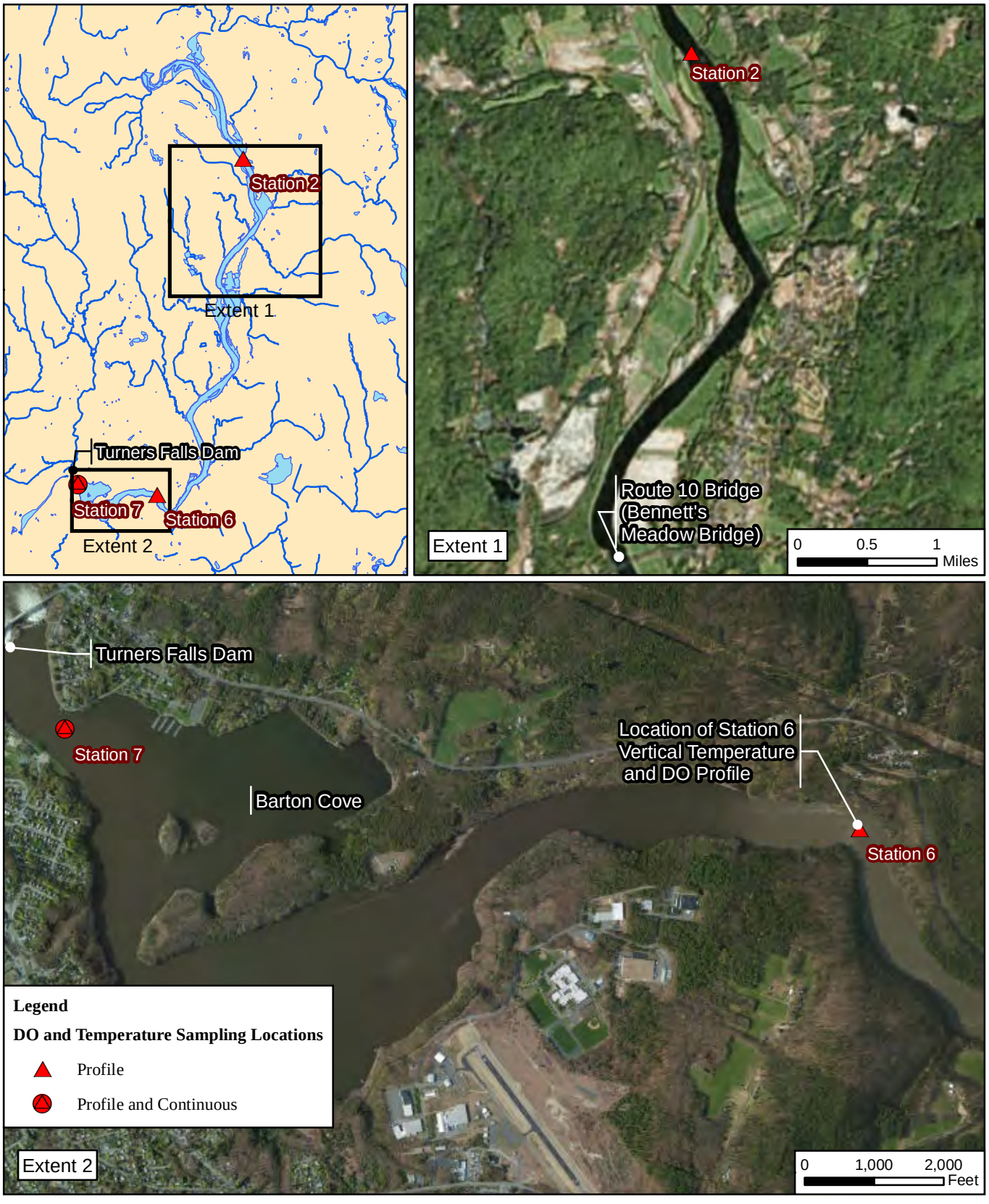
FIRSTLIGHT POWER RESOURCES

RELICENSING STUDY 3.2.1
WATER QUALITY MONITORING
FIELD SAMPLING PLAN

0 0.25 0.5 1 Miles

Figure 3.3:
Water Quality Sampling Locations Near the Northfield Mountain Tailrace

Path: W:\gis\studies\3_2_1\maps\Figure 3.3.mxd

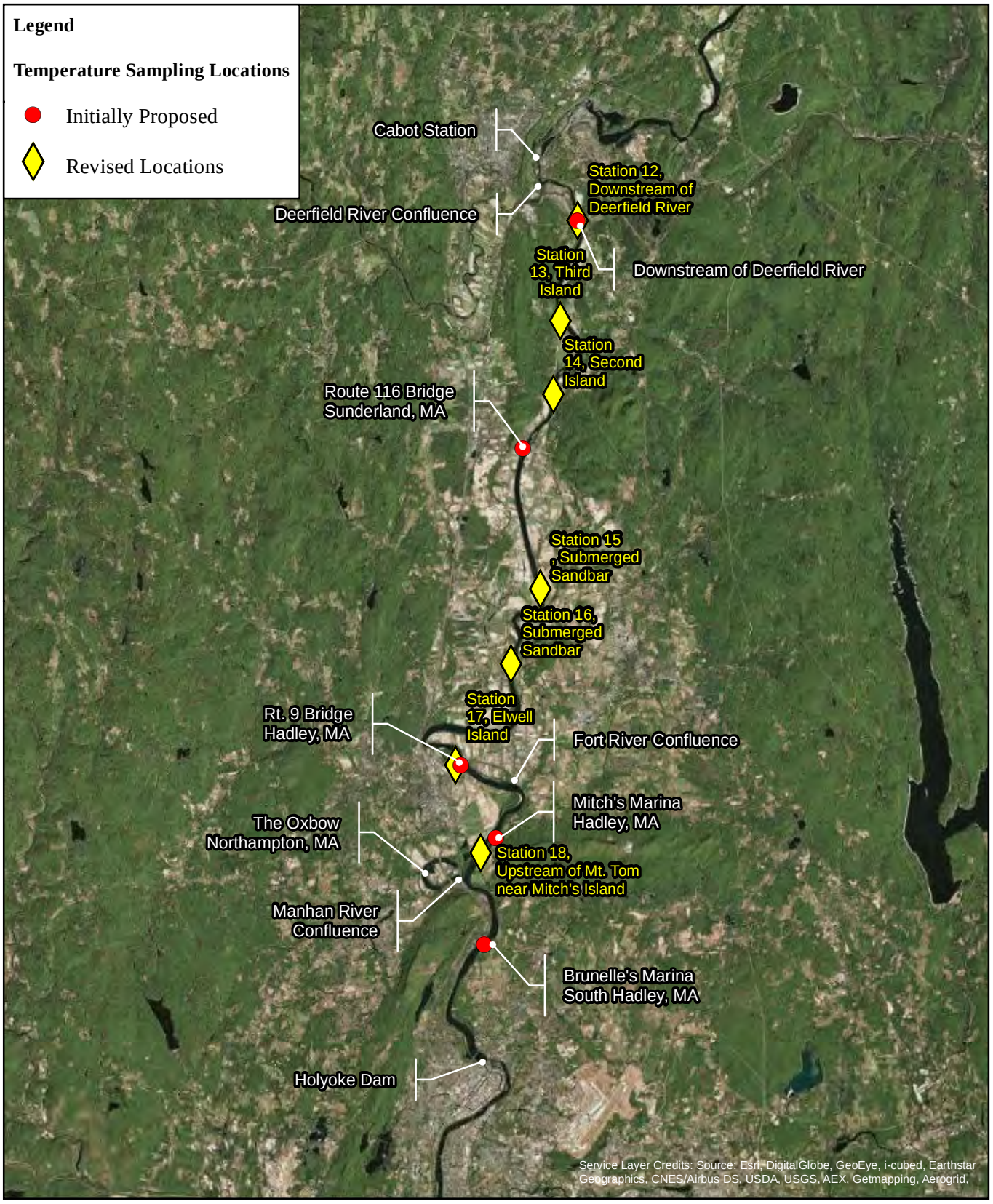


FIRSTLIGHT POWER RESOURCES

RELICENSING STUDY 3.2.1
WATER QUALITY MONITORING
FIELD SAMPLING PLAN

Figure 3.4:
Turners Falls Impoundment
Vertical Profile Locations

Path: W:\gis\studies\3_2_1\maps\Figure 3.4.mxd



FirstLight GDF SUEZ

N

FIRSTLIGHT POWER RESOURCES

RELICENSING STUDY 3.2.1
WATER QUALITY MONITORING
FIELD SAMPLING PLAN

0 1.25 2.5 5 Miles

Figure 3.5
Continuous Water Temperature Monitoring Locations
Cabot Station to Holyoke Dam
(revised based on stakeholder input)

Path: W:\gis\studies\3_2_1\maps\Figure 3.5.mxd

APPENDIX B – PHOTOGRAPH LOG OF WATER MONITORING SITES

Photo Number: 1
Site: Pauchaug Boat Launch
Date: 3/31/2015
View: From left bank
Note: Ice prevented boat launching

Photo Number: 2
Site: Sunderland Boat Launch
Date: 3/31/2015
View: From left bank
Note: Ice prevented boat launching

Photo Number: 3
Site: Water Quality Site 8
Date: 3/31/2015
View: Mid-channel looking downstream
Note: Station No. 1 on left bank

Photo Number: 4
Site: Water Quality Site 9
Date: 3/31/2015
View: Looking south across channel
Note: Rawson Island in background

Photo Number: 5
Site: Water Quality Site 1
Date: 4/3/2015
View: Upstream
Note: White Buoy

Photo Number: 6
Site: Water Quality Site 2
Date: 4/3/2015
View: Upstream
Note: Vertical Profile Site

Photo Number: 7
Site: Water Quality Site 3
Date: 4/3/2015
View: Upstream
Note: White Buoy

Photo Number: 8
Site: Water Quality Site 4
Date: 4/3/2015
View: Looking across at Northfield Mountain Tailrace
Note: White Buoy

Photo Number: 9
Site: Water Quality Site 5
Date: 4/3/2015
View: Upstream
Note: White Buoy

Photo Number: 10
Site: Water Quality Site 6
Date: 4/3/2015
View: Across channel looking at right bank
Note: Vertical Profile in deep hole

Photo Number: 11
Site: Water Quality Site 7
Date: 10/9/2015
View: Looking Downstream
Note: Orange Buoy

Photo Number: 12
Site: Water Quality Site 10
Date: 10/23/2015
View: From Left Bank of Canal
Note: Meter Suspended from Cable

Photo Number: 13
Site: Water Quality Site 11
Date: 10/8/2015
View: Upstream from right side of channel
Note: White Buoy

Photo Number: 14
Site: Water Quality Site 12
Date: 10/8/2015
View: Upstream looking at left bank
Note: Tethered to tree

Photo Number: 15
Site: Water Quality Site 13
Date: 10/8/2015
View: Upstream from river right channel
Note: Tethered to right bank

Photo Number: 16
Site: Water Quality Site 14
Date: 10/8/2015
View: Upstream from river right channel
Note: Tethered to right bank

Photo Number: 17
Site: Water Quality Site 15
Date: 10/8/2015
View: Upstream
Note: Tethered to tree on left bank

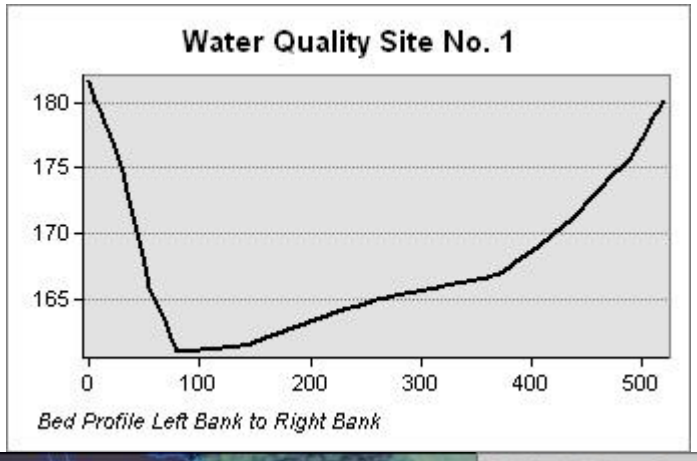
Photo Number: 18
Site: Water Quality Site 16
Date: 4/10/2015
View: Upstream
Note: Tethered to tree on left bank

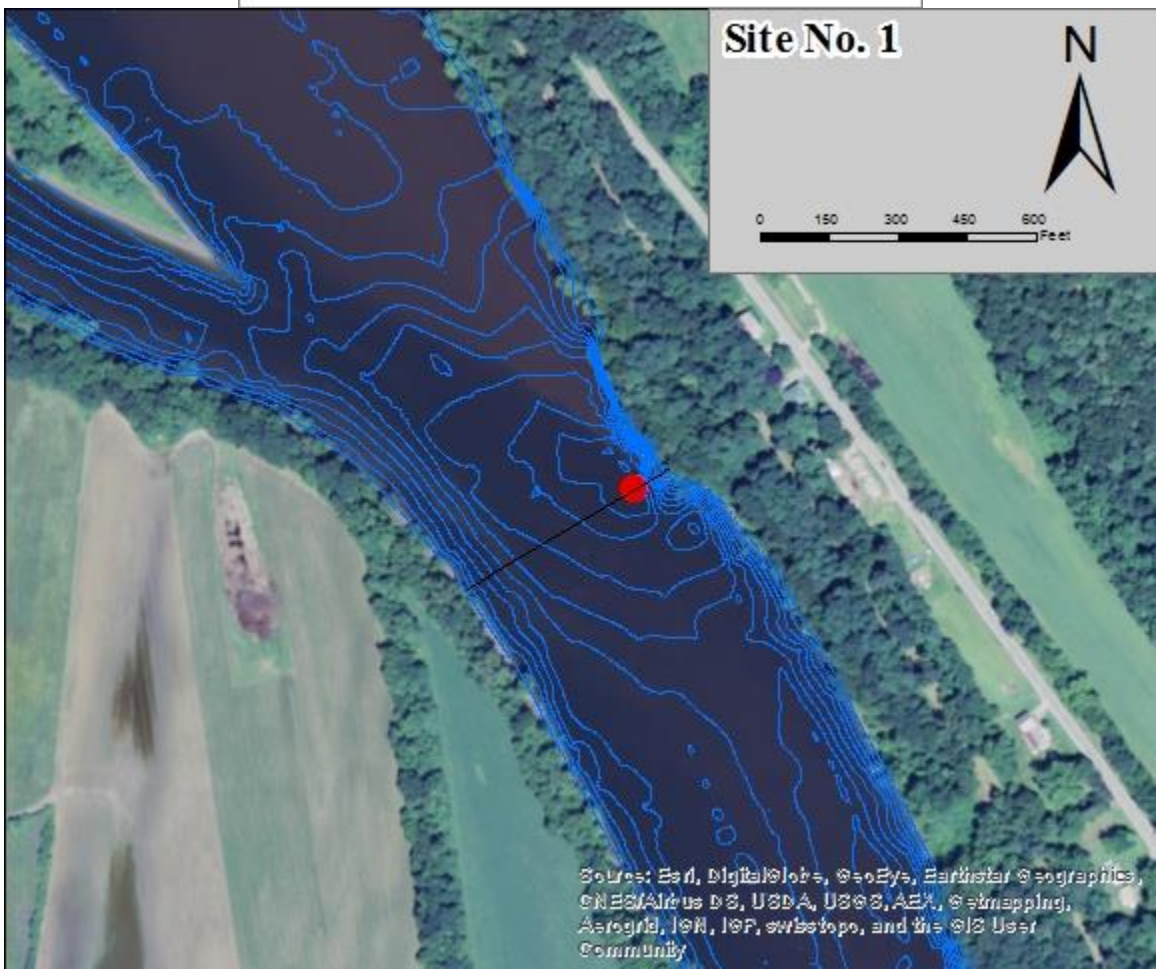
Photo Number: 19
Site: Water Quality Site 17
Date: 10/8/2015
View: Downstream
Note: Tethered to tree on Elwell Island

Photo Number: 20
Site: Water Quality Site 18
Date: 4/10/2015
View: Upstream at Water Quality Site 18
Note: Tethered to tree on Mitch's Island

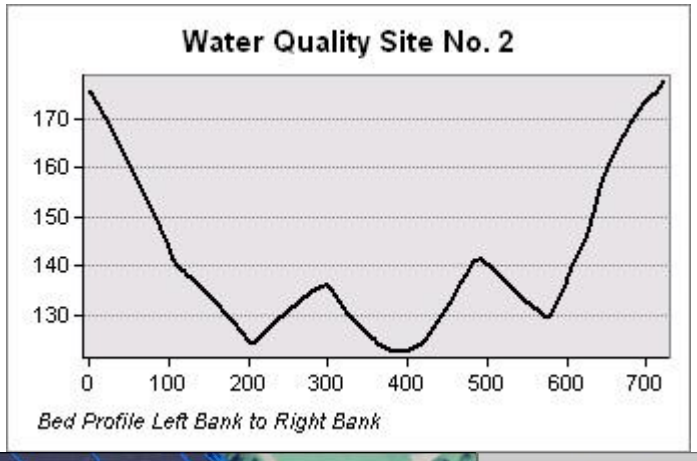
APPENDIX C- MAPS OF EACH WATER QUALITY MONITORING SITE

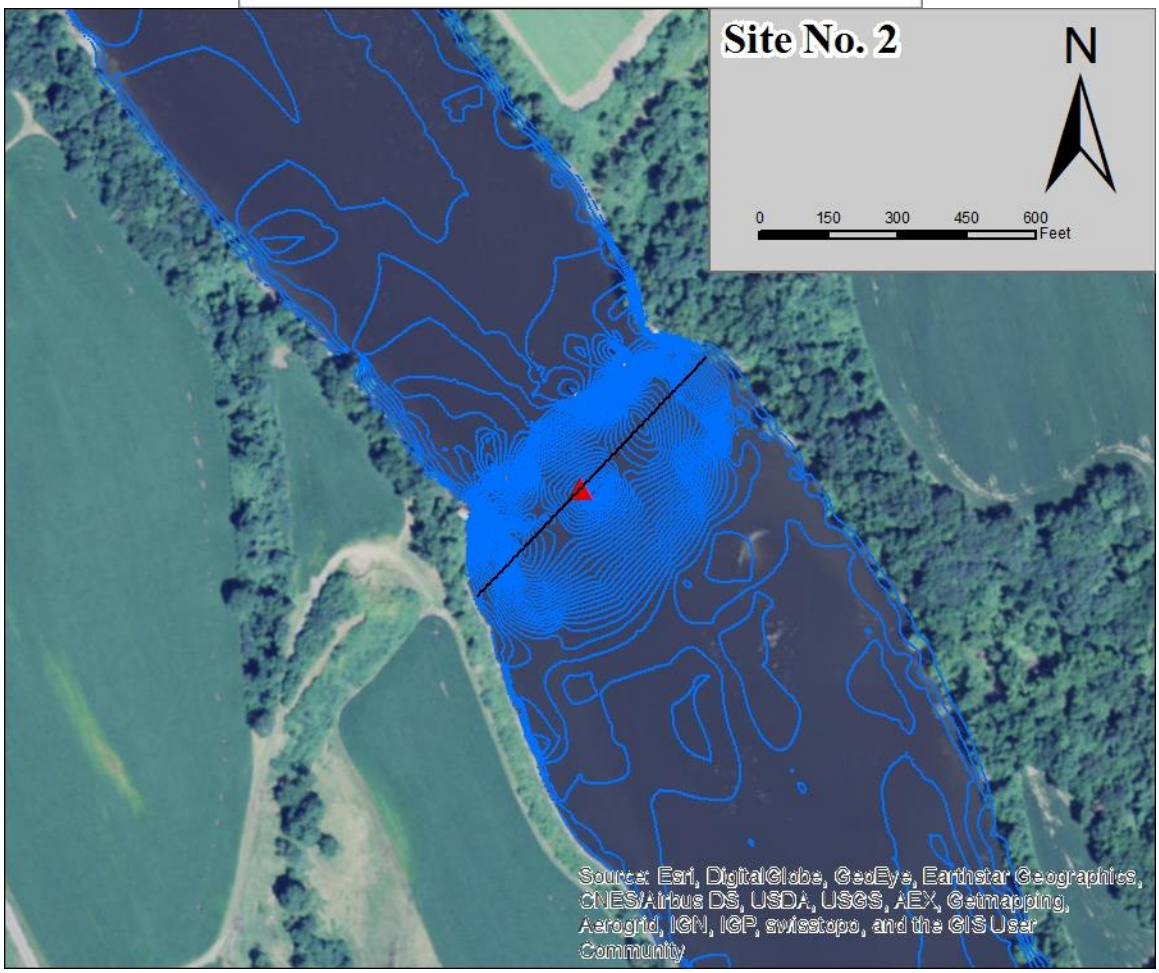
Connecticut River-Turners Falls Impoundment
Water Quality Site No. 1
Type: Continuous DO and Temperature
Location: Below Ashuelot River Confluence
Logger Depth: 5 ft
Approximate River Depth: 23 ft



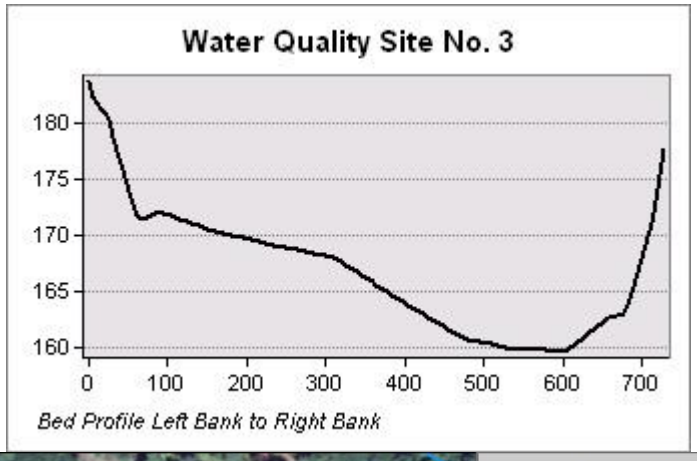


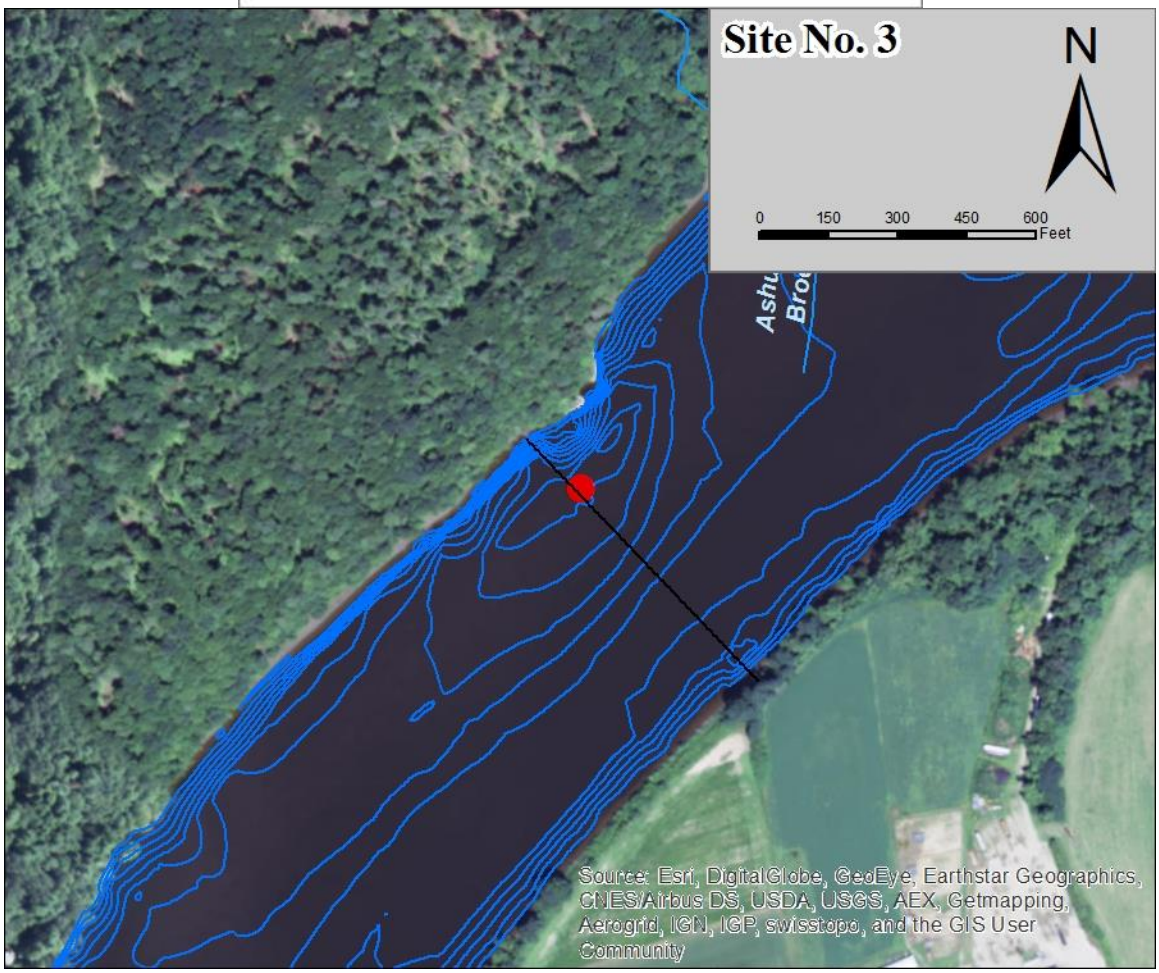
Connecticut River-Turners Falls Impoundment
Water Quality Site No. 2
Type: Profile DO and Temperature
Location: Deep area upstream of Northfield Mountain
Logger Depth: NA
Approximate River Depth: 60 ft



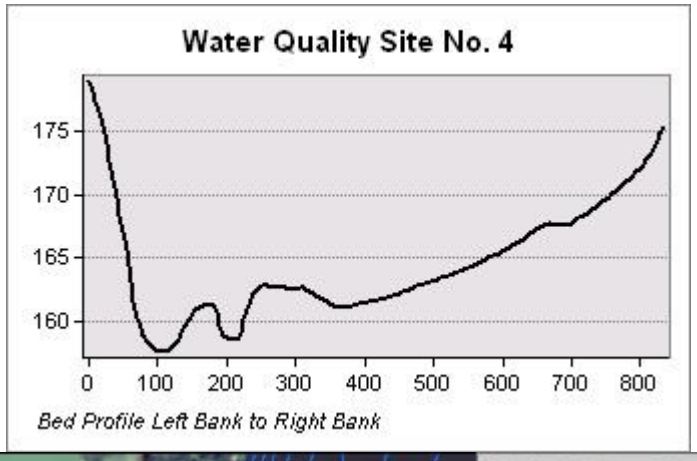


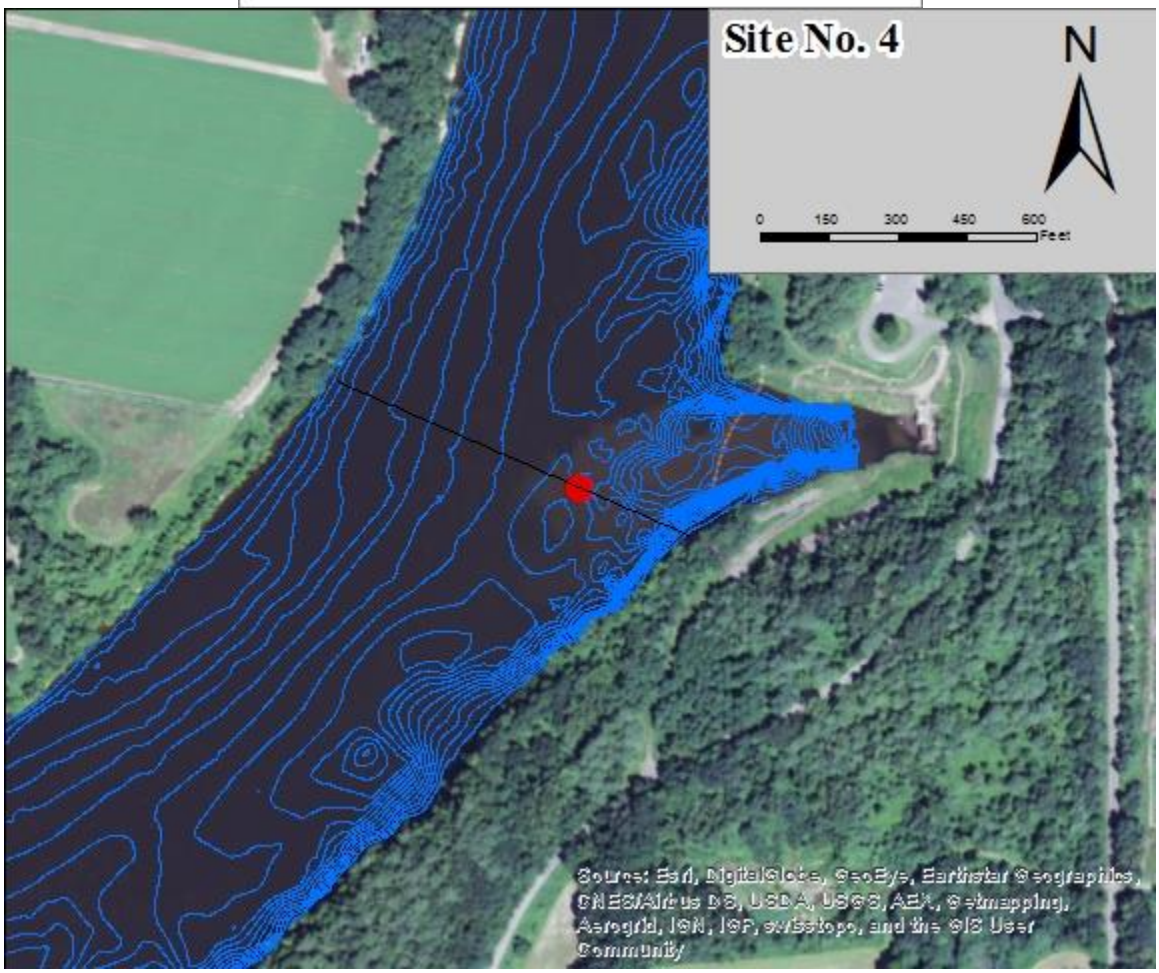
Connecticut River-Turners Falls Impoundment
Water Quality Site No. 3
Type: Continuous DO and Temperature
Location: Above the Northfield Mountain Discharge
Logger Depth: 6 ft
Approximate River Depth: 26 ft



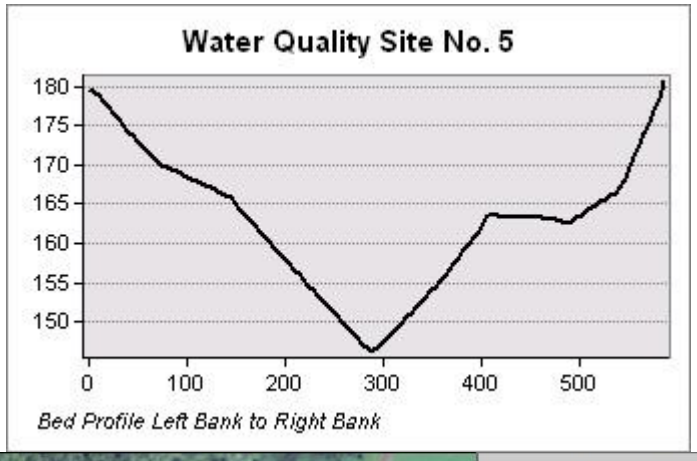


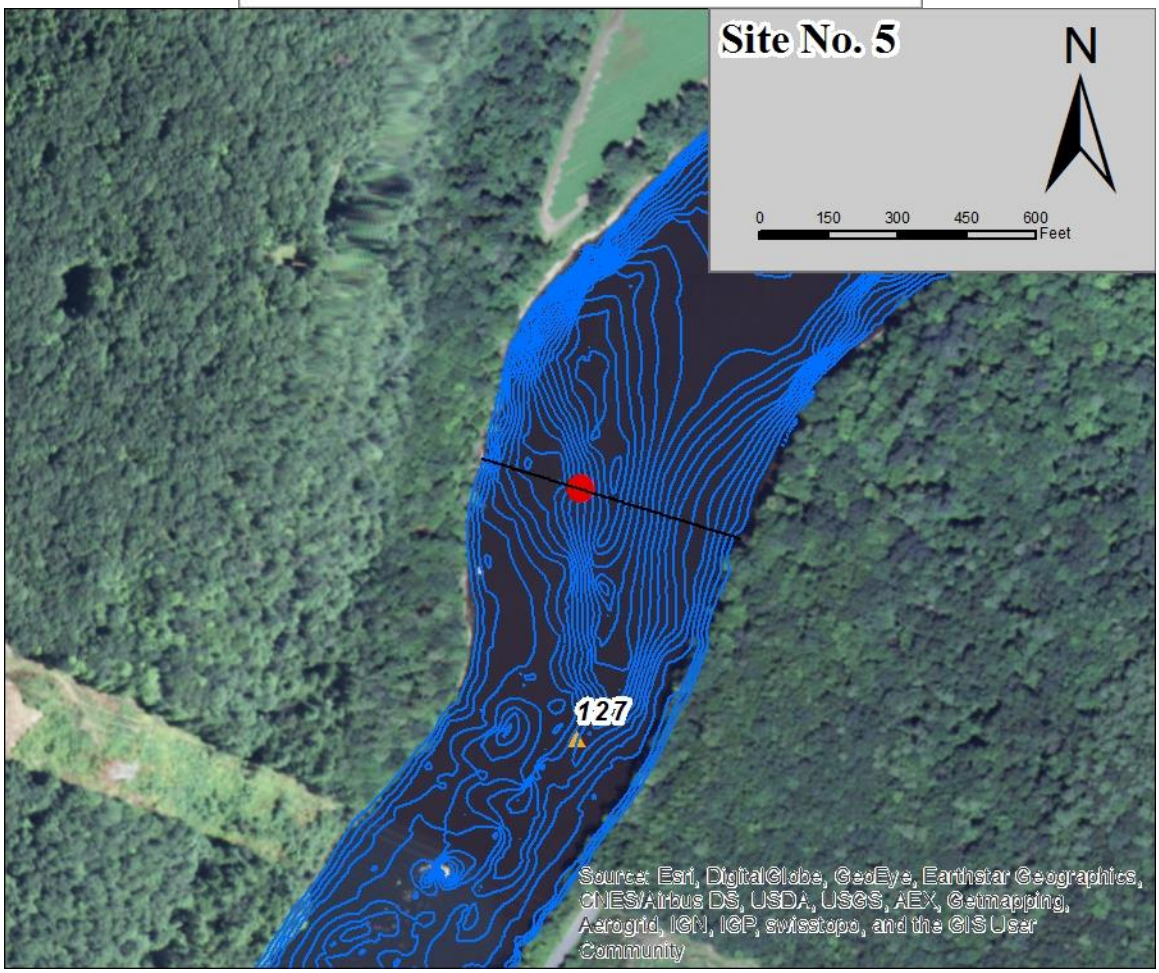
Connecticut River-Turners Falls Impoundment
Water Quality Site No. 4
Type: Continuous DO and Temperature
Location: Northfield Mountain Tailrace
Logger Depth: 5 ft
Approximate River Depth: 20 ft



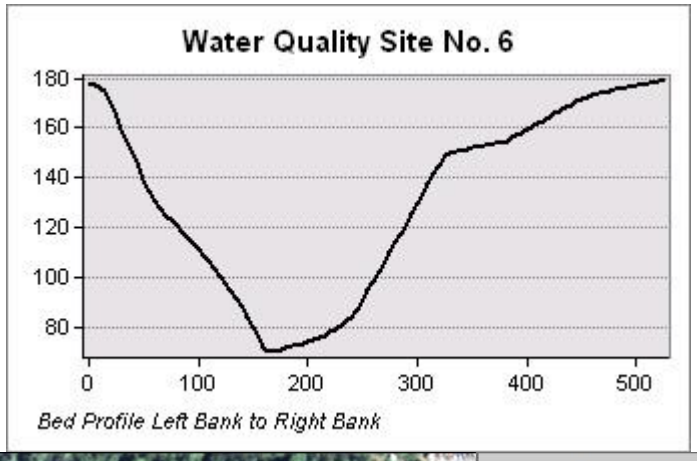


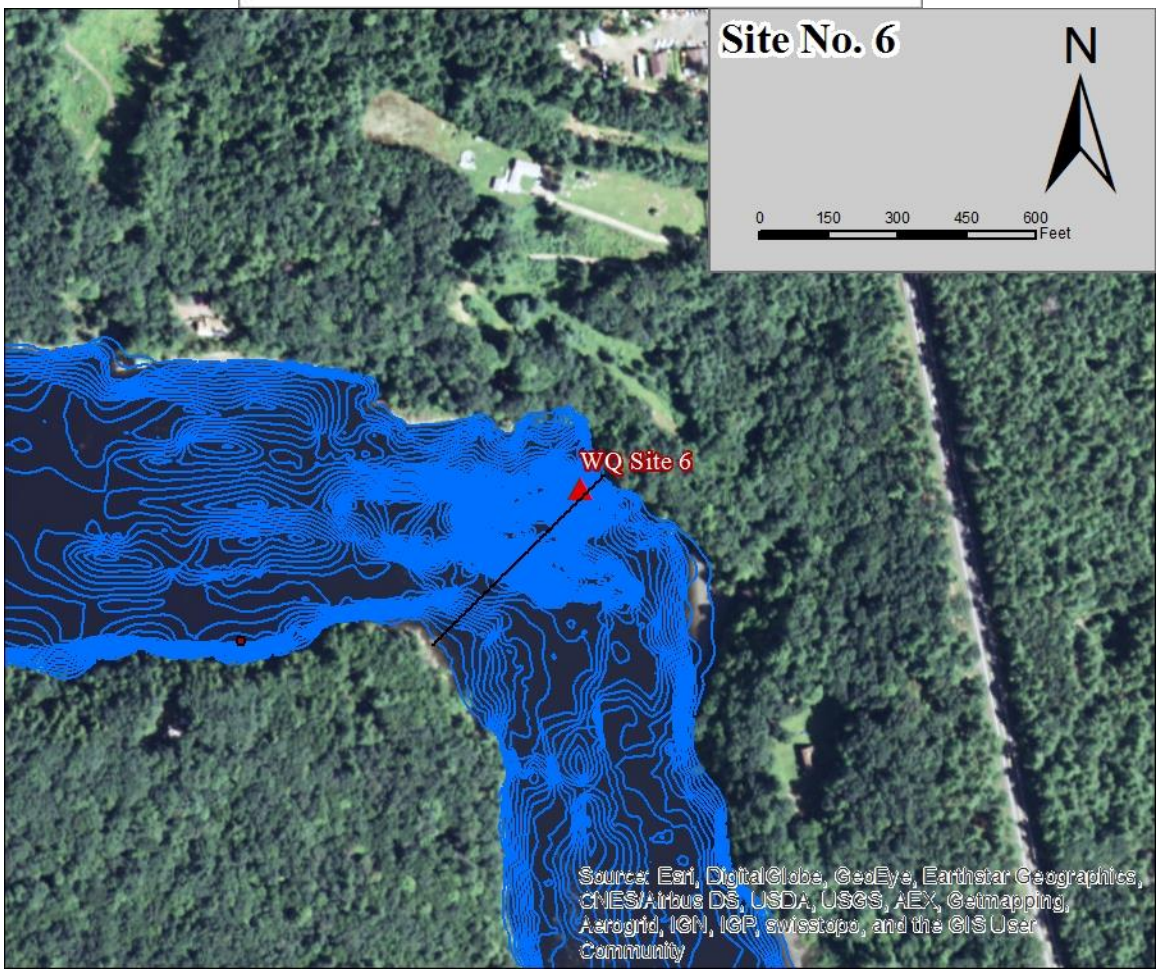
Connecticut River-Turners Falls Impoundment
Water Quality Site No. 5
Type: Continuous DO and Temperature
Location: Below the Northfield Mountain Tailrace
Logger Depth: 10 ft
Approximate River Depth: 40 ft



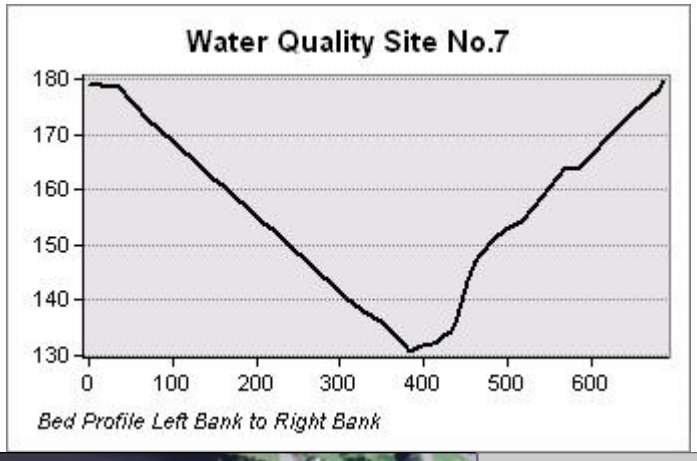


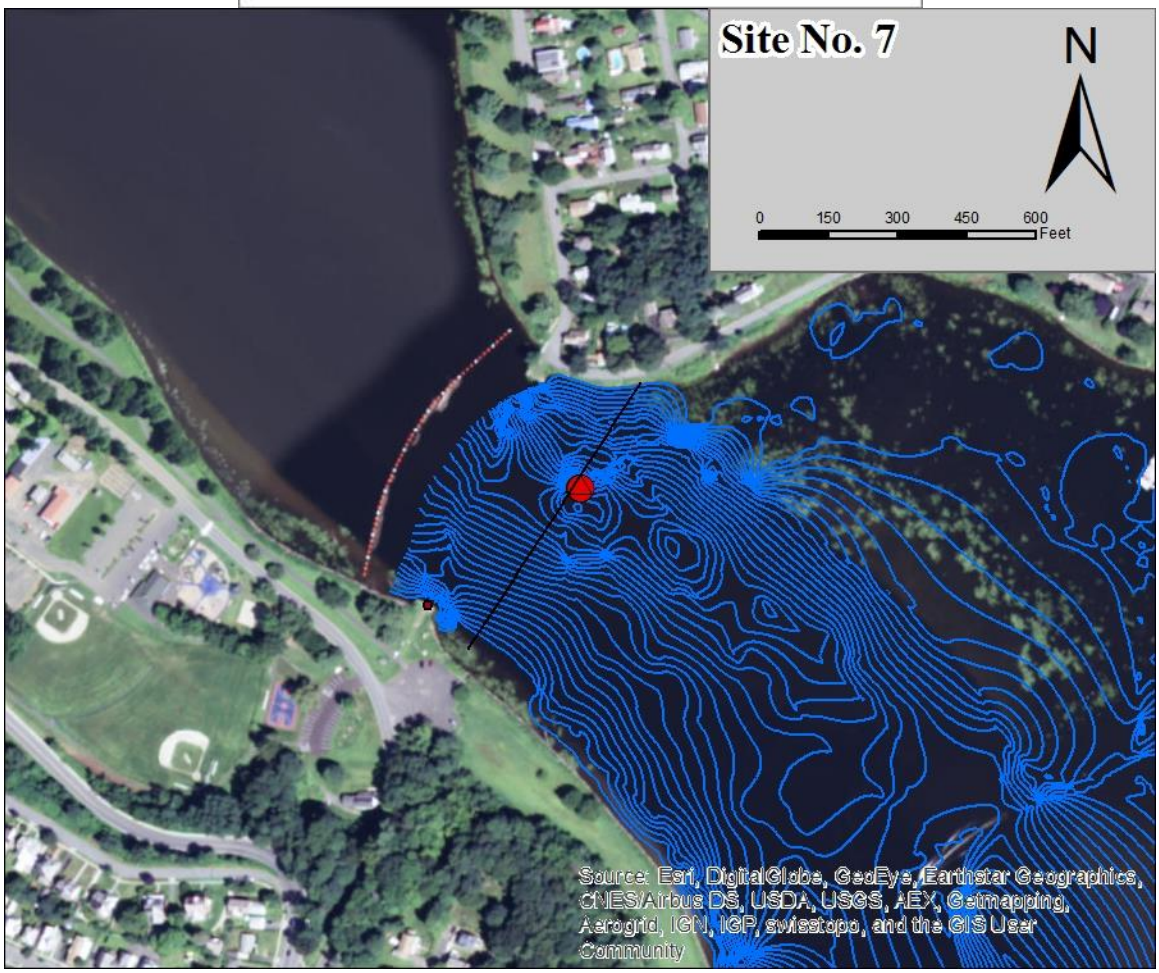
Connecticut River-Turners Falls Impoundment
Water Quality Site No. 6
Type: Profile DO and Temperature
Location: Deepest area of Turners Falls Impoundment
Logger Depth: NA
Approximate River Depth: 120 ft



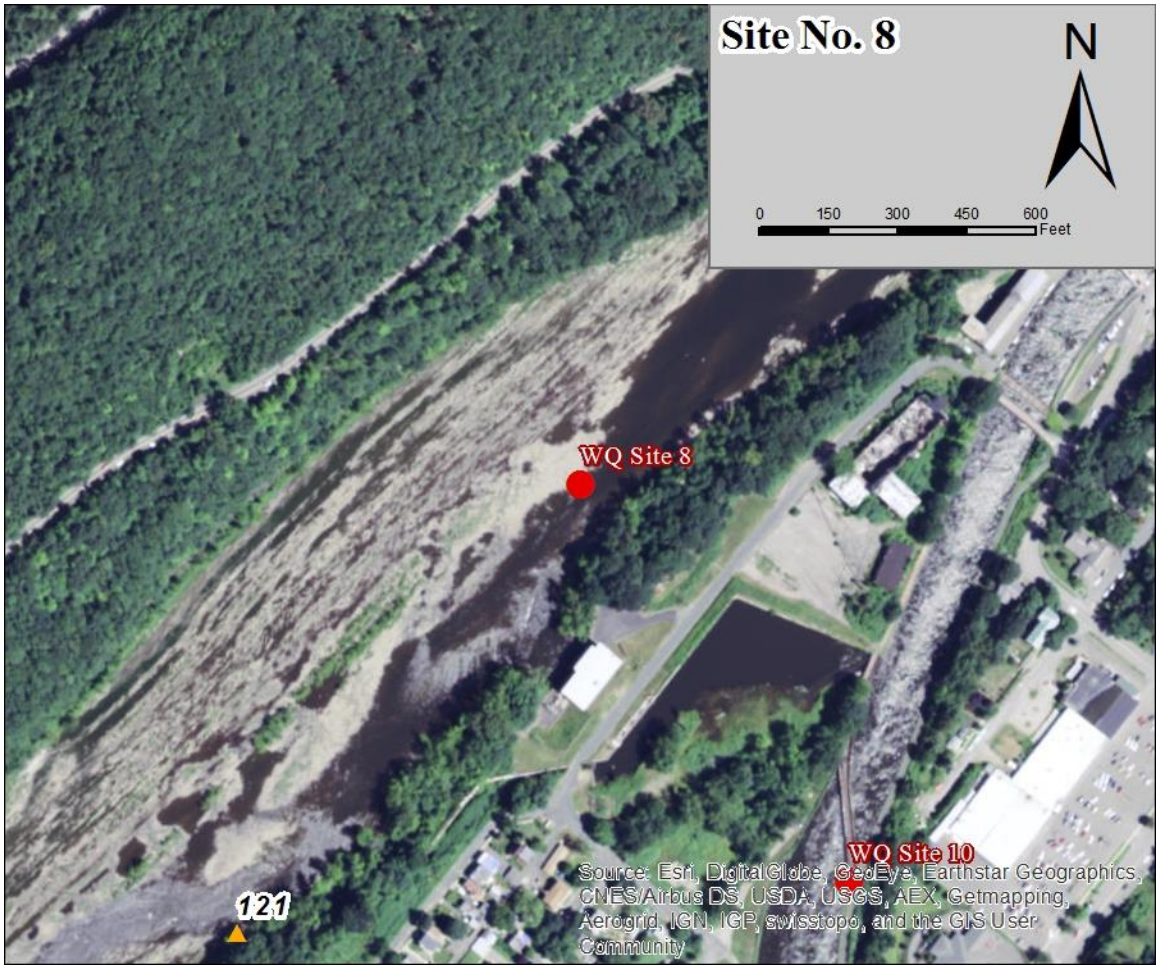


Connecticut River-Turners Falls Impoundment
Water Quality Site No. 7
Type: Profile and Continuous DO and Temperature
Location: Upstream of the Turners Falls Dam at Boat Barrier
Logger Depth: 12 ft
Approximate River Depth: 50 ft

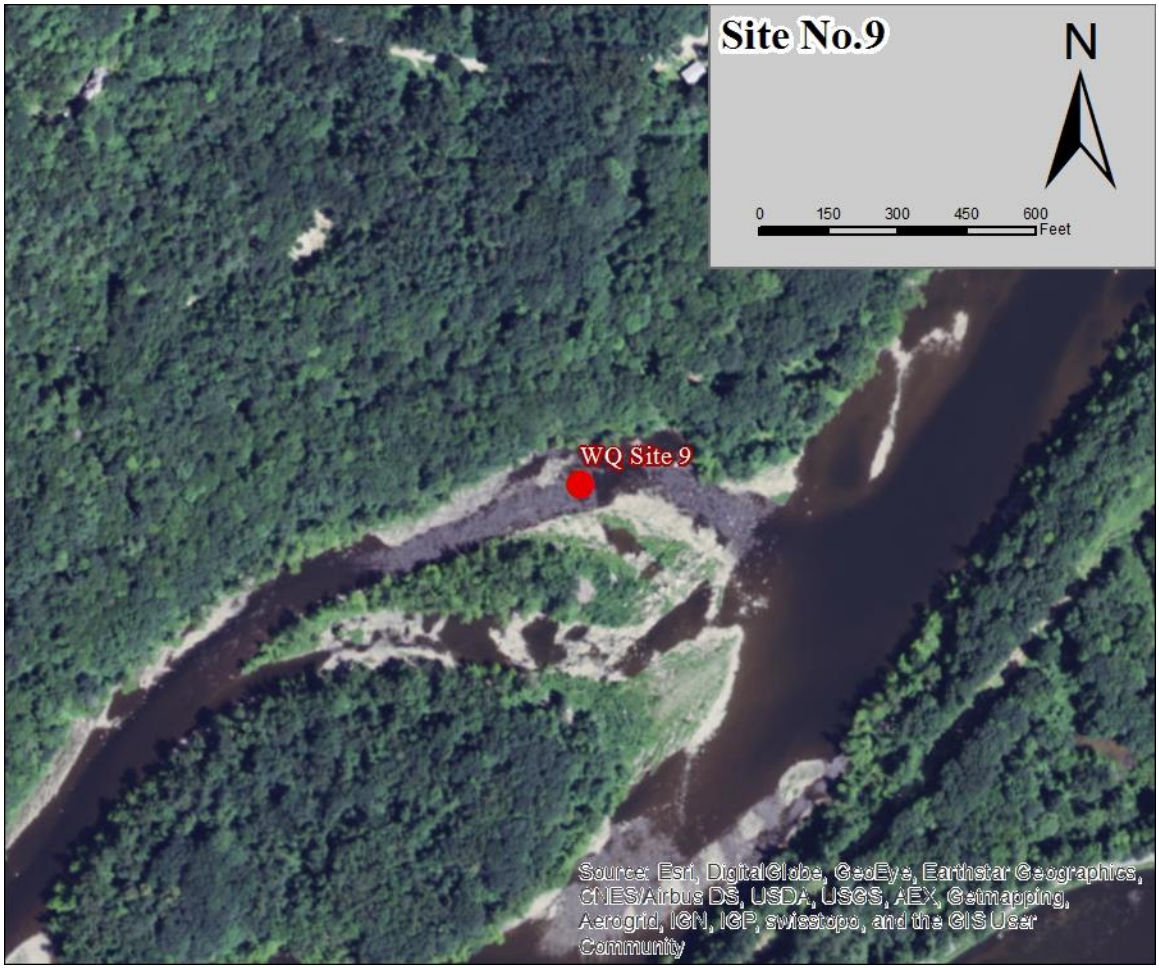




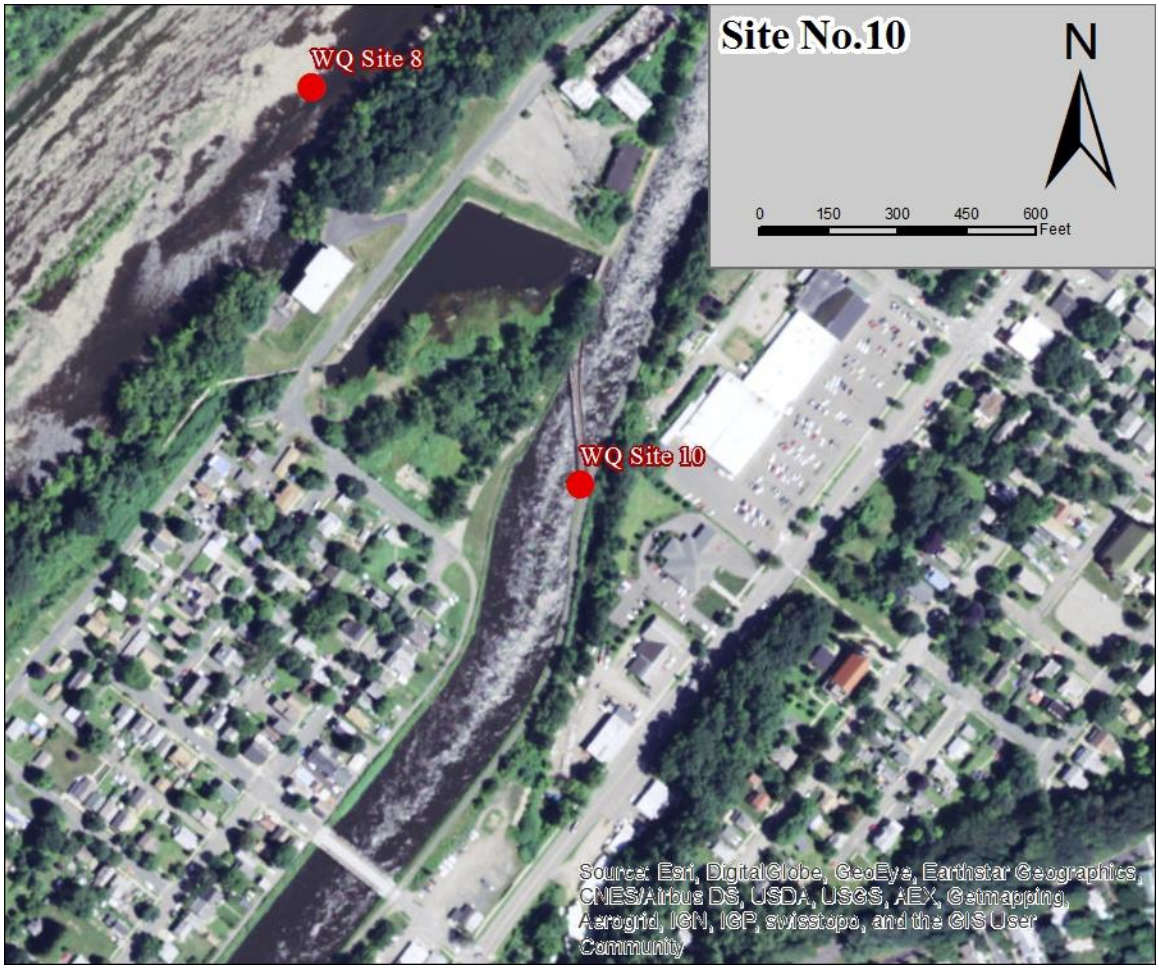
Connecticut River-Bypass Reach
Water Quality Site No. 8
Type: Continuous DO and Temperature
Location: Upstream of Station No. 1
Logger Location: Bottom
Approximate River Depth: ~3 ft under low flow



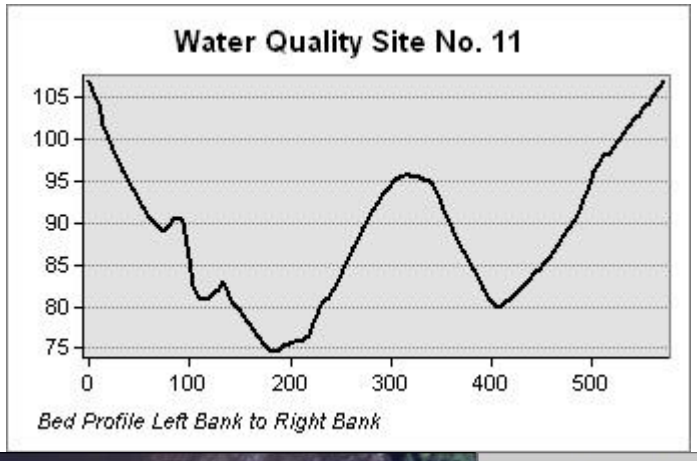
Connecticut River-Bypass Reach
Water Quality Site No. 9
Type: Continuous DO and Temperature
Location: Upstream of Rock Dam; west channel at Rawson Island
Logger Depth: Bottom
Approximate River Depth: ~2 ft under low flow

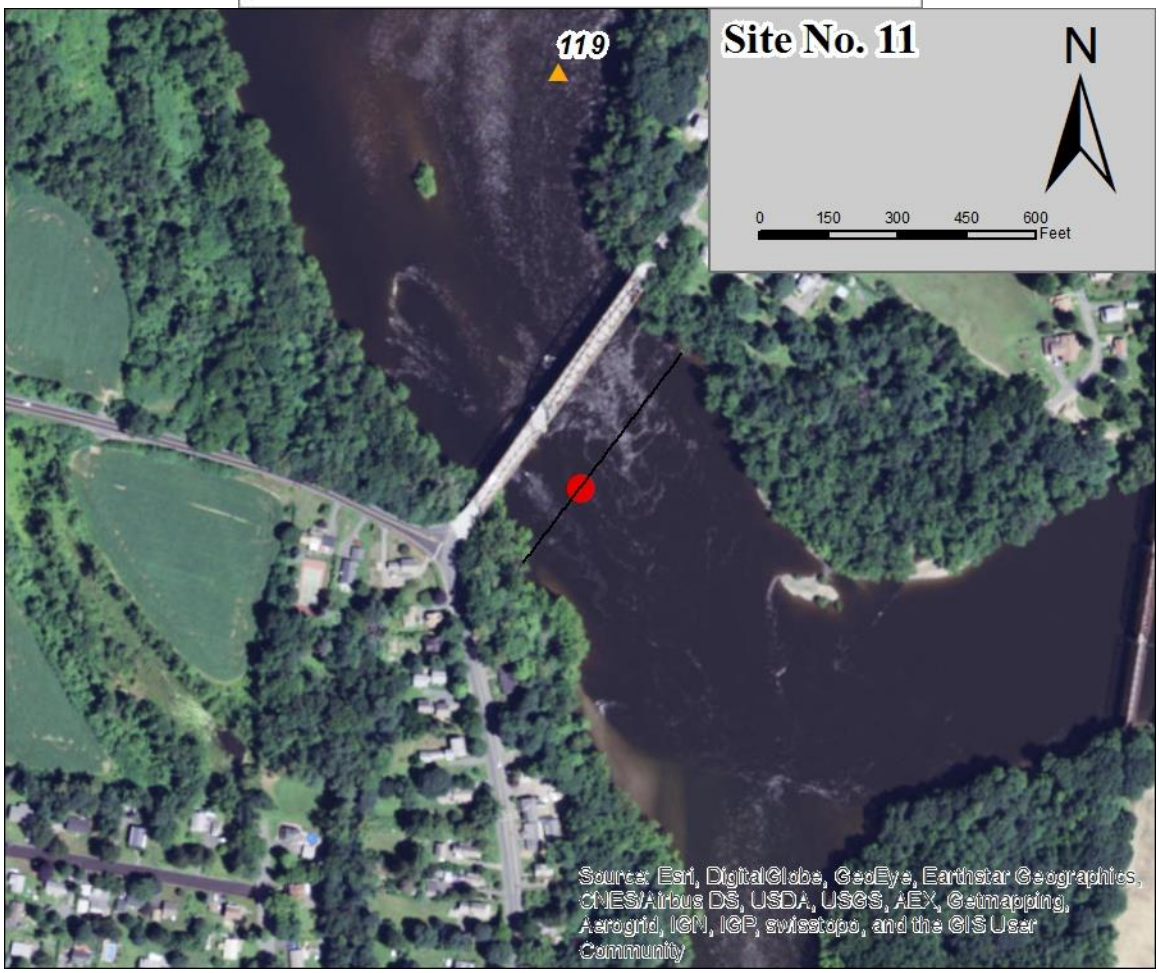


Turners Falls Power Canal
Water Quality Site No. 10
Type: Continuous DO and Temperature
Location: At the Railroad Bridge
Logger Depth: 10 ft
Canal Depth: 20 ft

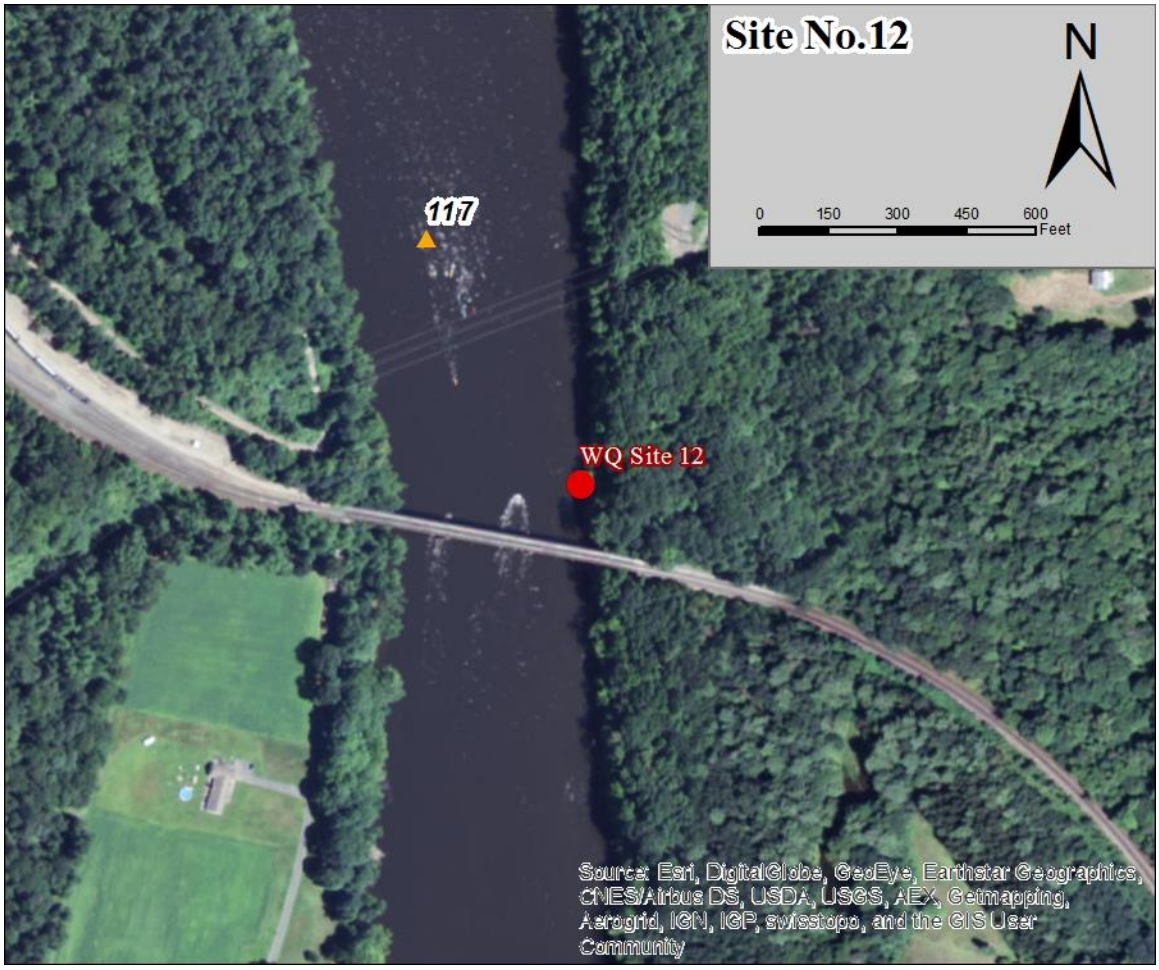


Connecticut River Below Cabot Station
Water Quality Site No. 11
Type: Continuous DO and Temperature
Location: Below Cabot Station tailrace, upstream of Deerfield River confluence
Logger Depth: 5 ft
Approximate River Depth: 22 ft

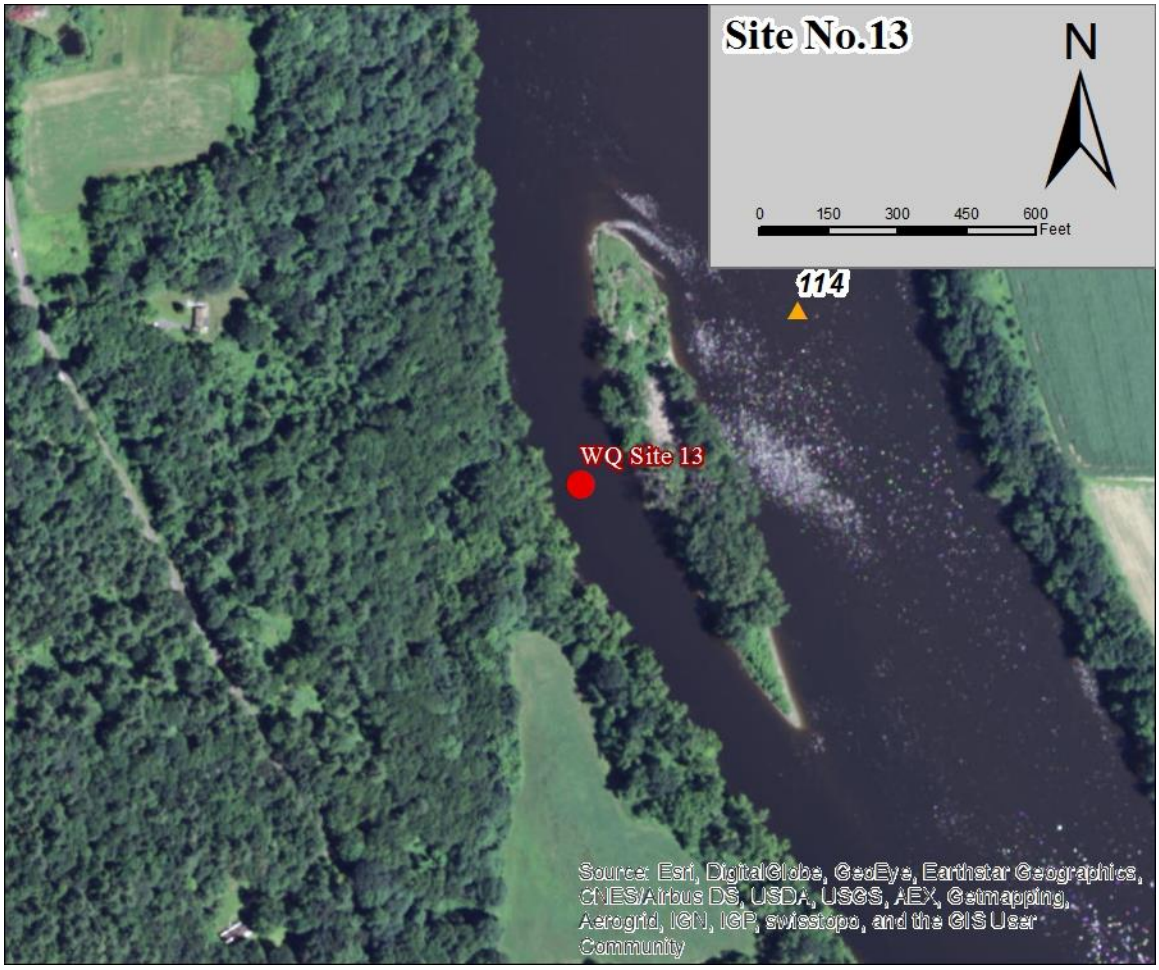




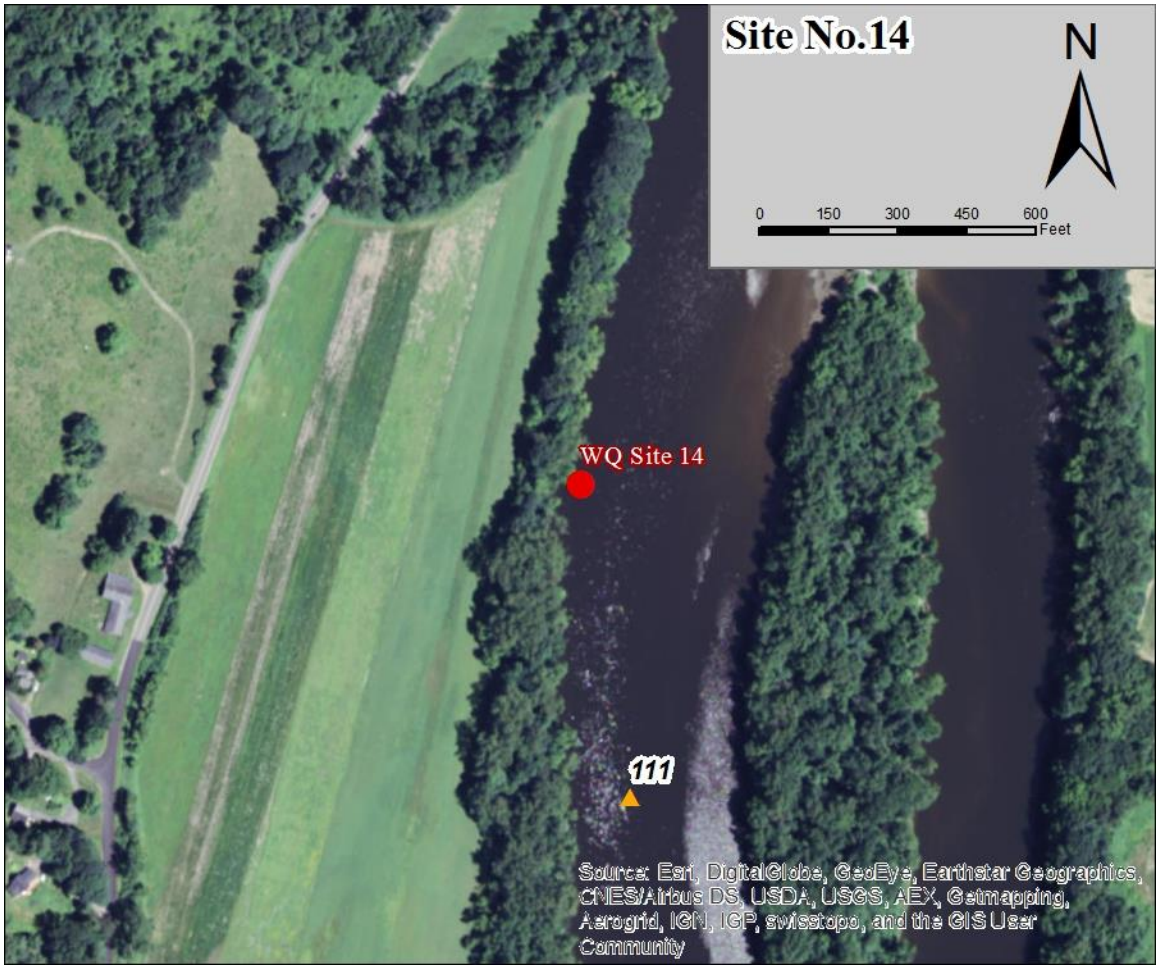
Connecticut River-Cabot Station to Holyoke Dam
Water Quality Site No. 12
Type: Continuous Temperature
Location: Downstream of Deerfield River Confluence at railroad bridge
Logger Location: Bottom
Approximate River Depth: 7 ft



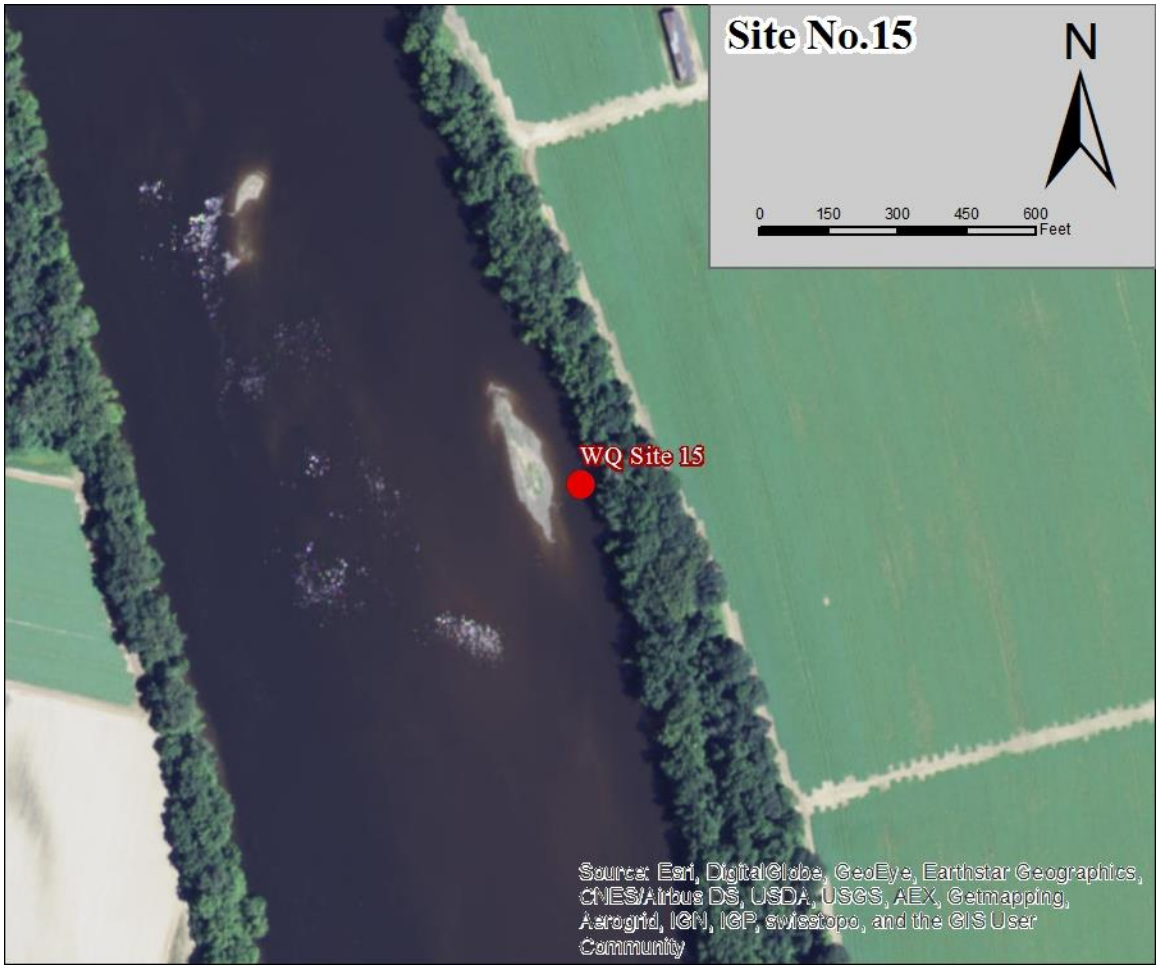
Connecticut River-Cabot Station to Holyoke Dam
Water Quality Site No. 13
Type: Continuous Temperature
Location: Third Island
Logger Location: Bottom
Approximate River Depth: 6 ft



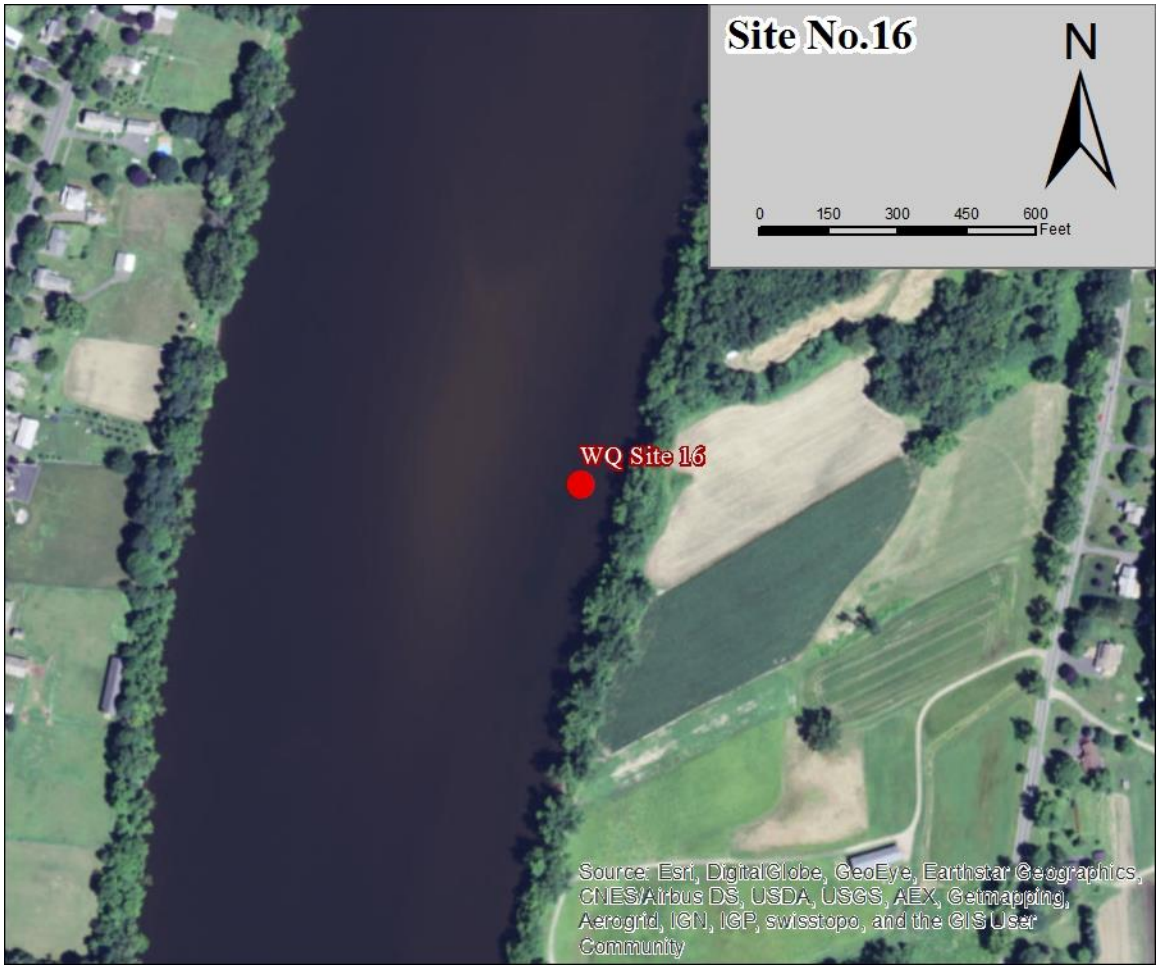
Connecticut River-Cabot Station to Holyoke Dam
Water Quality Site No. 14
Type: Continuous Temperature
Location: Second Island
Logger Location: Bottom
Approximate River Depth: 5 ft



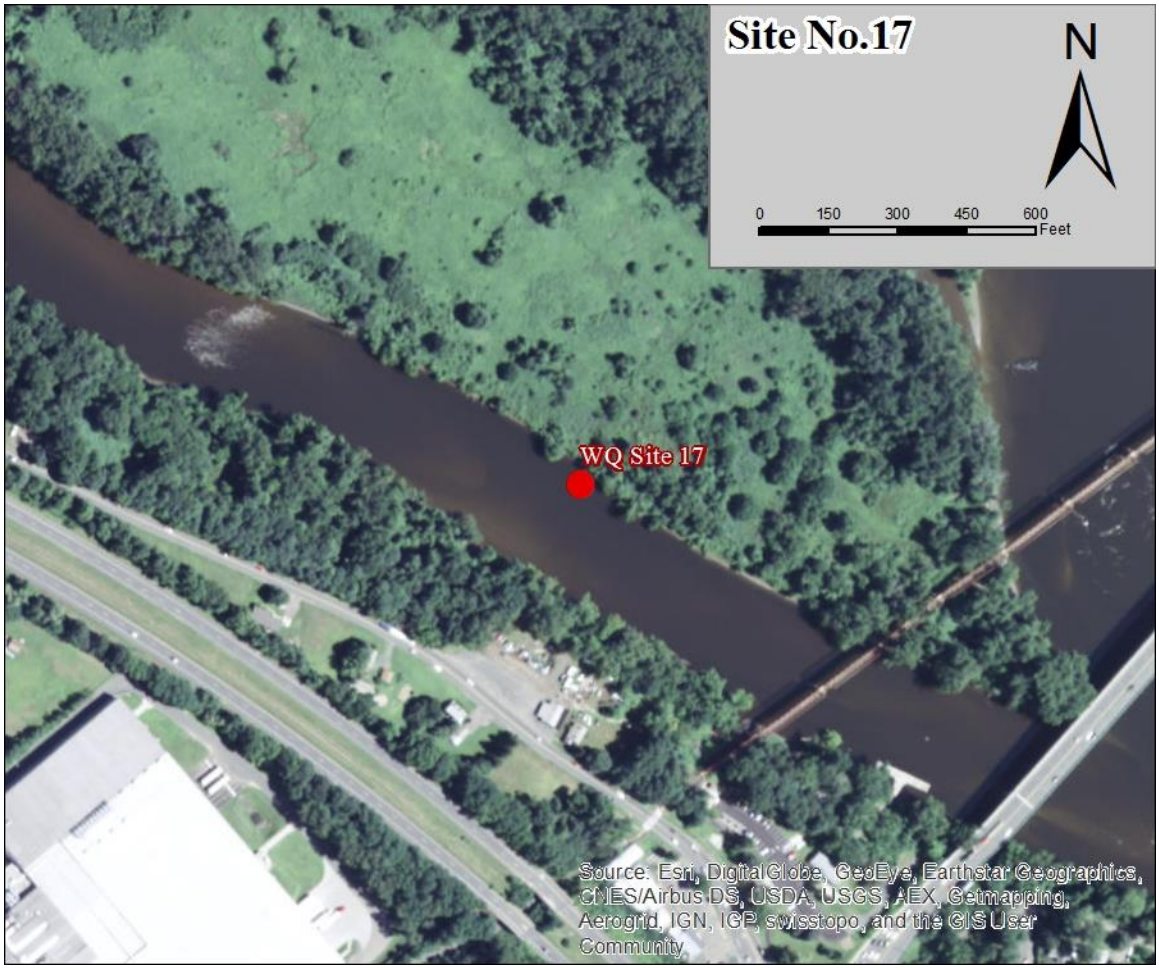
Connecticut River-Cabot Station to Holyoke Dam
Water Quality Site No. 15
Type: Continuous Temperature
Location: Submerged shallow bar
Logger Location: Bottom
Approximate River Depth: 8 ft



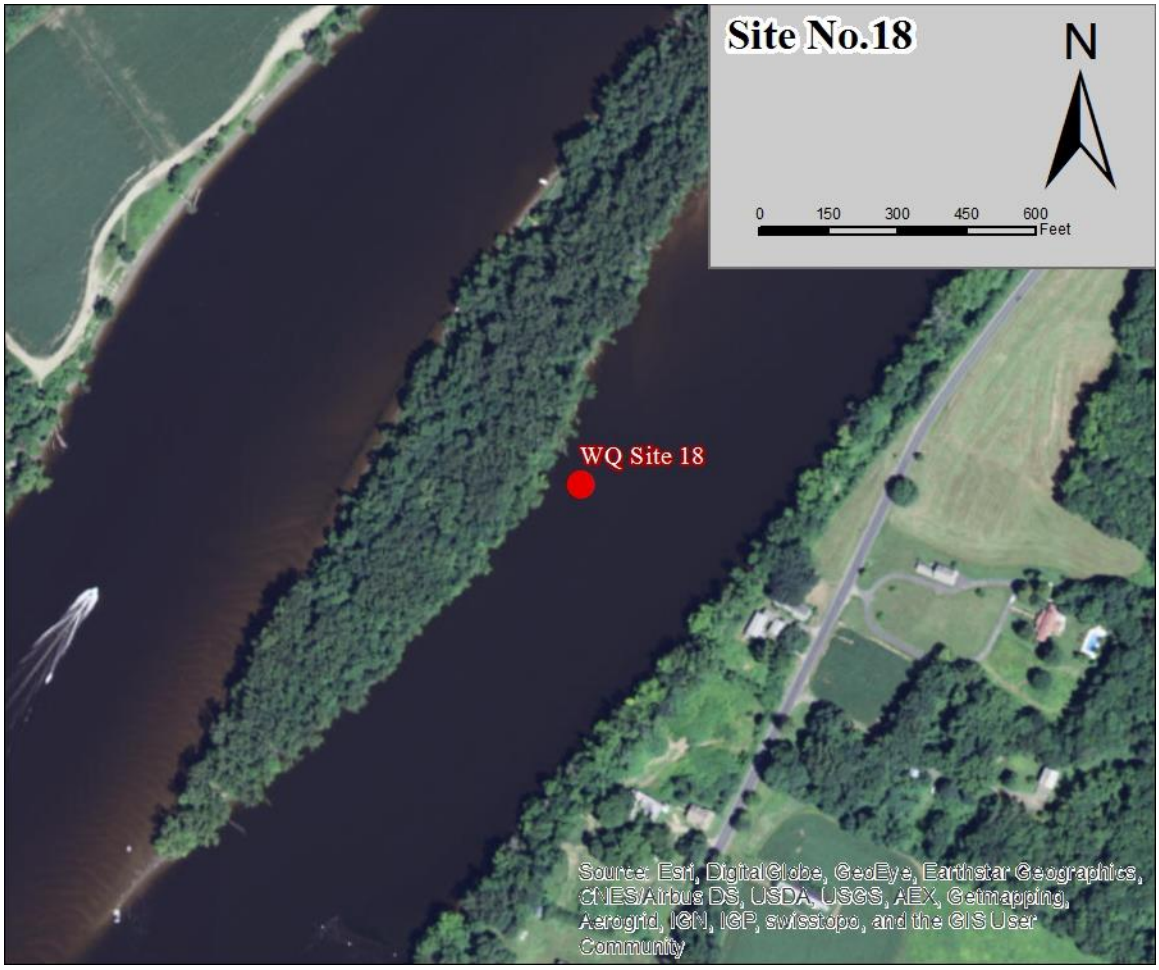
Connecticut River-Cabot Station to Holyoke Dam
Water Quality Site No. 16
Type: Continuous Temperature
Location: Submerged shallow bar
Logger Location: Bottom
Approximate River Depth: 6 ft



Connecticut River-Cabot Station to Holyoke Dam
Water Quality Site No. 17
Type: Continuous Temperature
Location: River right channel at Elwell Island
Logger Location: Bottom
Approximate River Depth: 9 ft



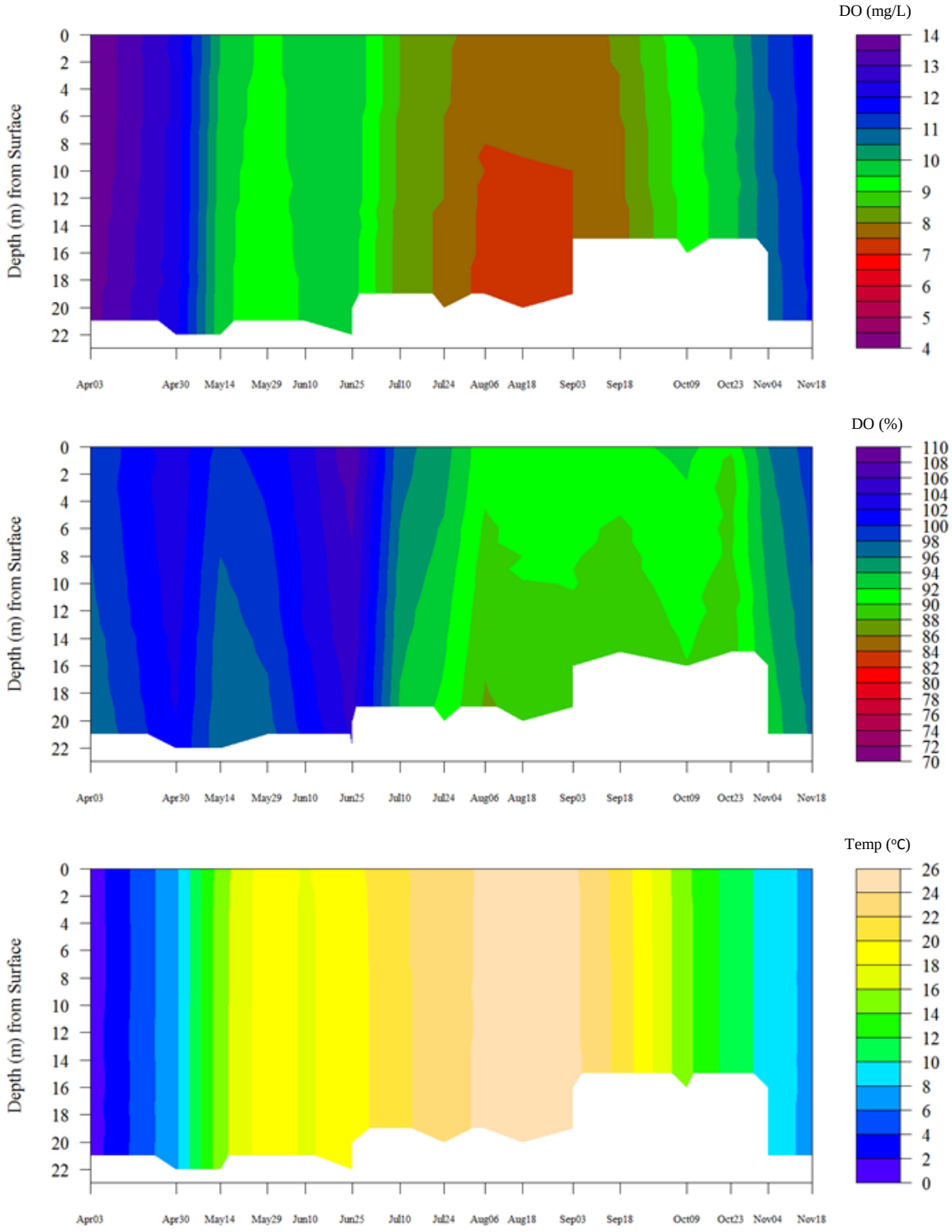
Connecticut River-Cabot Station to Holyoke Dam
Water Quality Site No. 18
Type: Continuous Temperature
Location: Mitch's Island
Logger Location: Bottom
Approximate River Depth: 6 ft



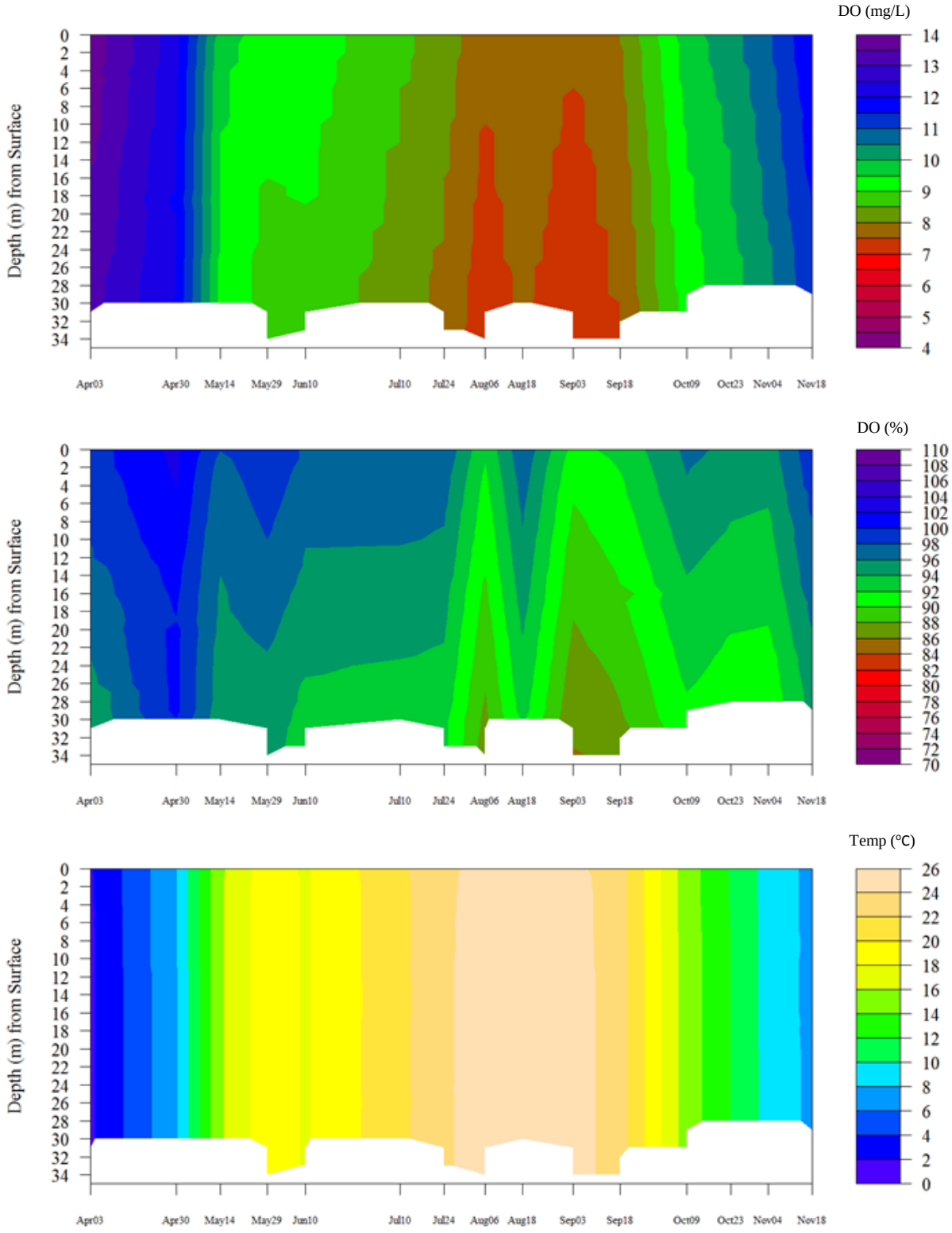
APPENDIX D- ISOPLETH CHARTS OF DISSOLVED OXYGEN AND TEMPERATURE

Each isopleth represents the water column for each sampling event as well as interpolated values between sampling events. Different colors in the isopleths equate to different values for each parameter (i.e., temperature and DO) as indicated in the sidebar of each figure. Vertical stripes of color over time indicate a well-mixed water column because a fairly consistent value is seen from the surface of the water to the bottom of the profile. Horizontal bands of color indicate a parameter increases or decreases with depth.

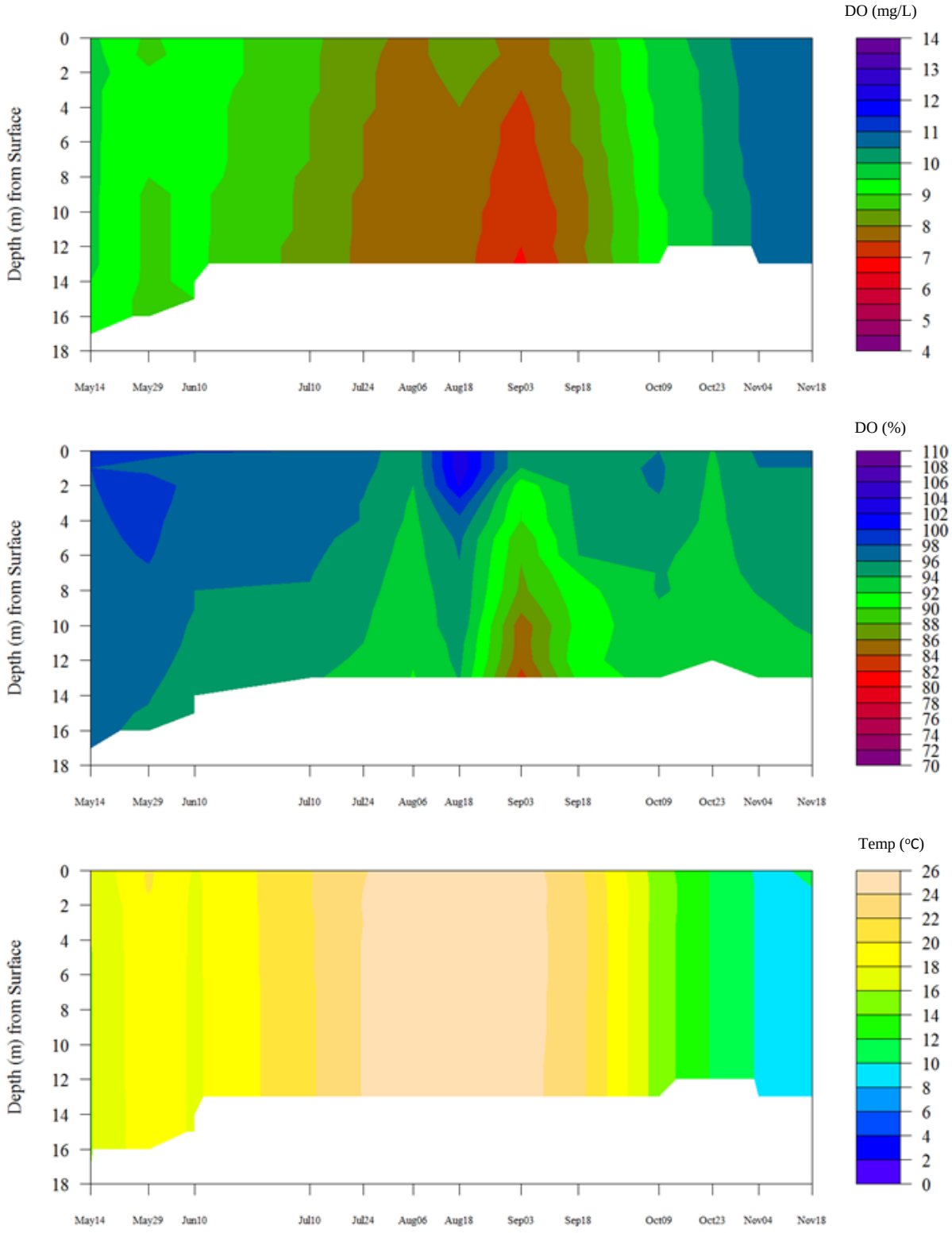
Turners Falls Impoundment Isopleths
Station 2: DO (mg/L), DO (%), Temp (ºC)



Turners Falls Impoundment Isopleths
Station 6: DO (mg/L), DO (%), Temp (ºC)

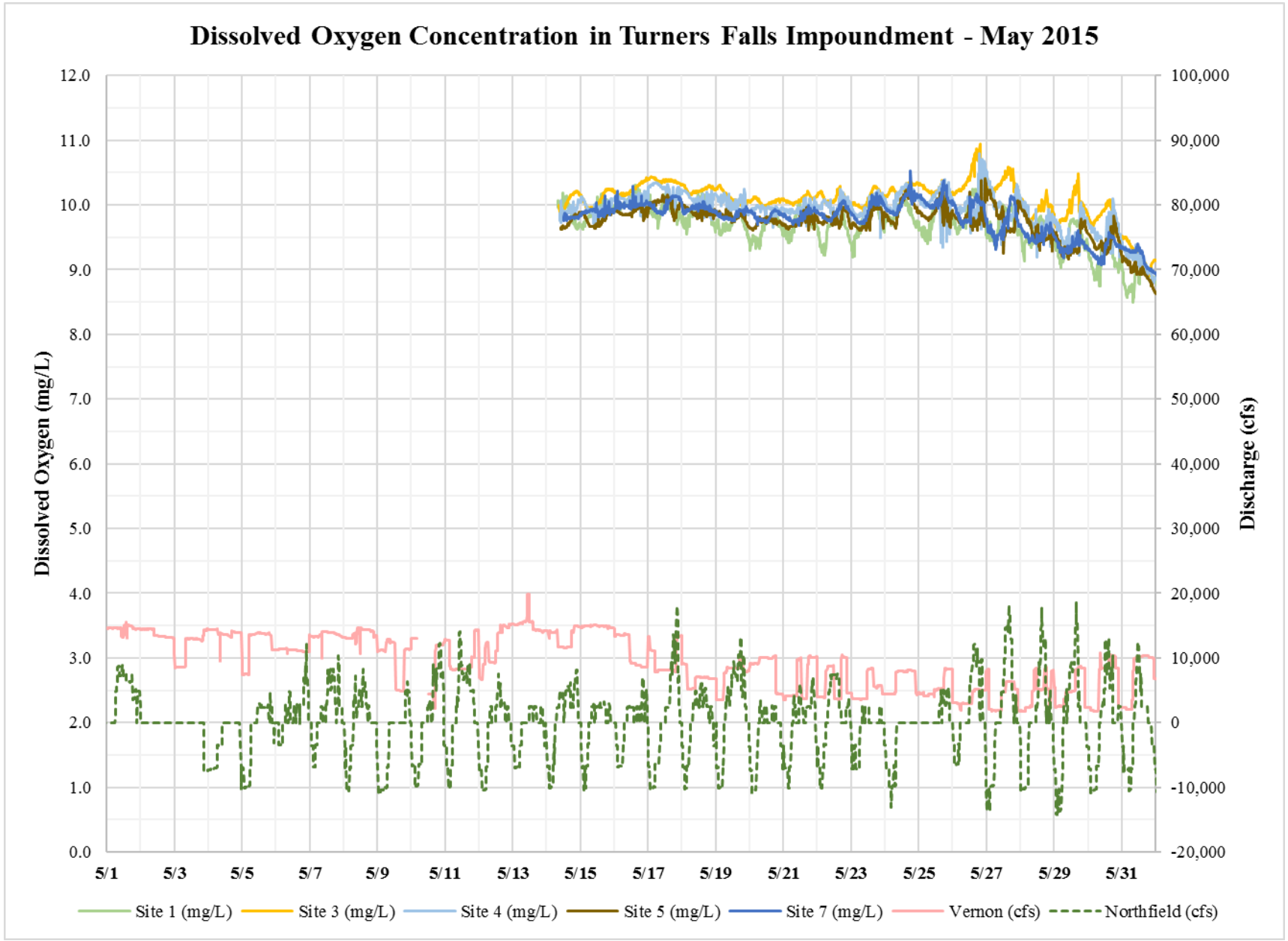


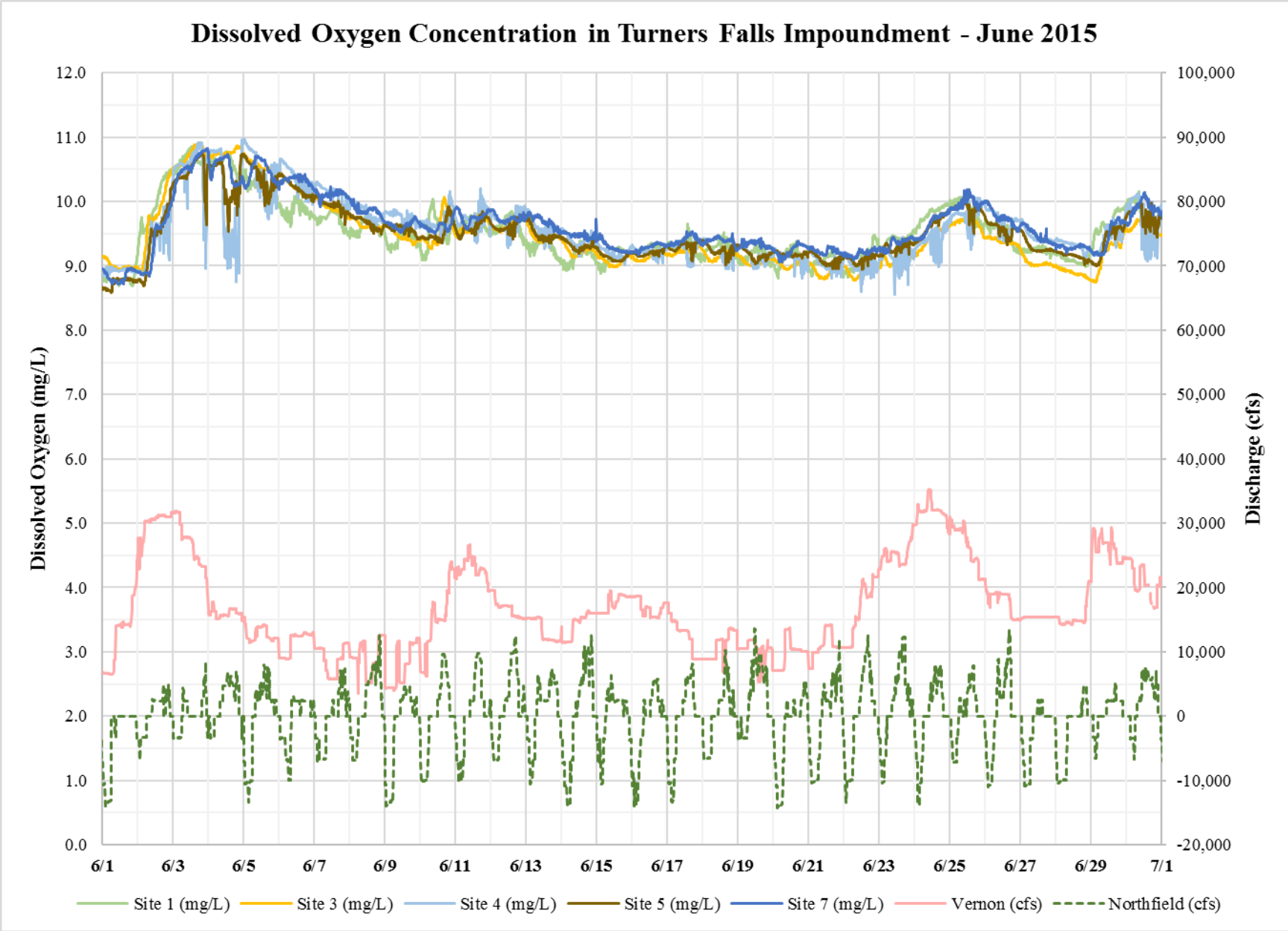
Turners Falls Impoundment Isopleths
Station 7: DO (mg/L), DO (%), Temp (ºC)

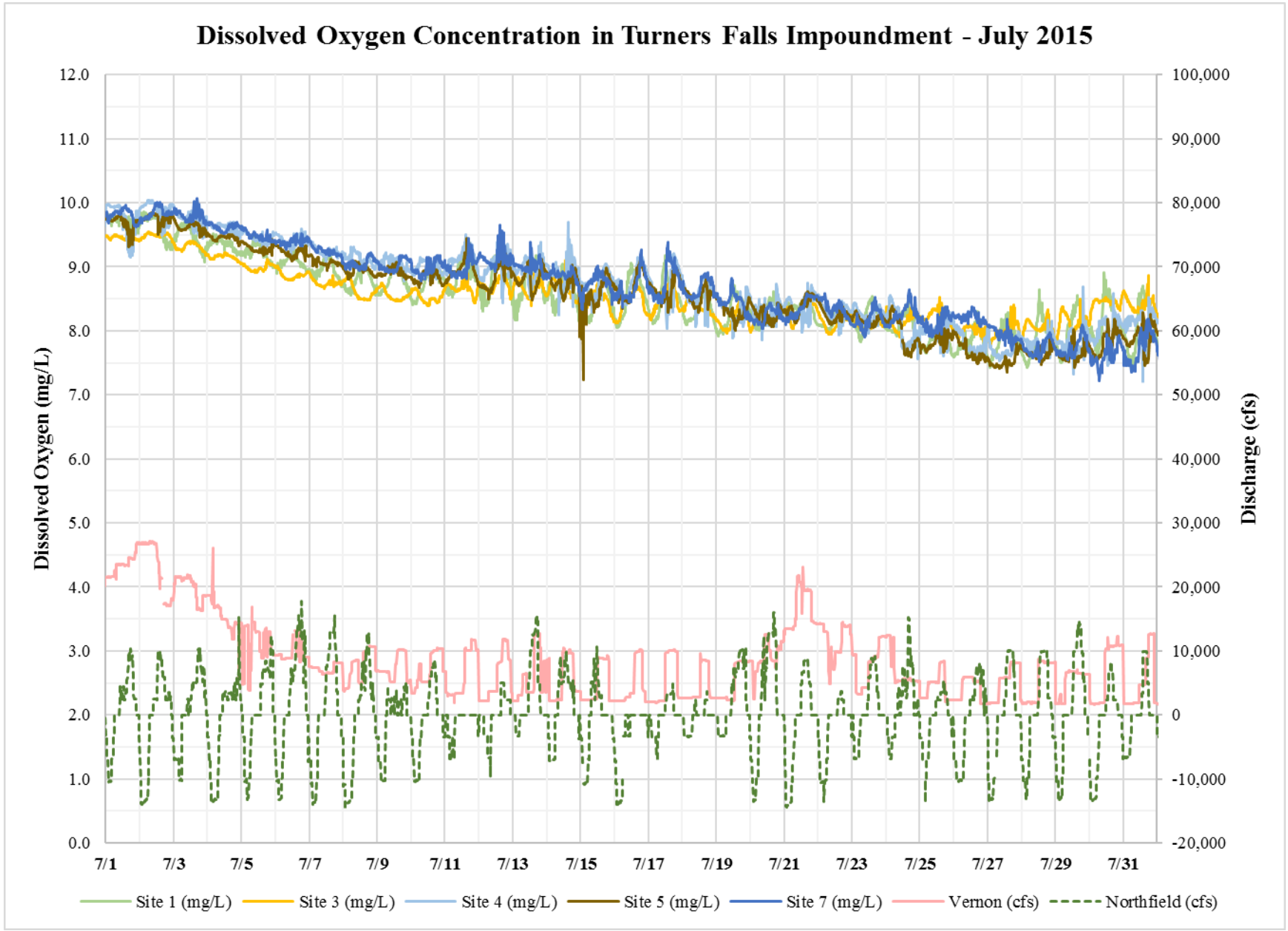


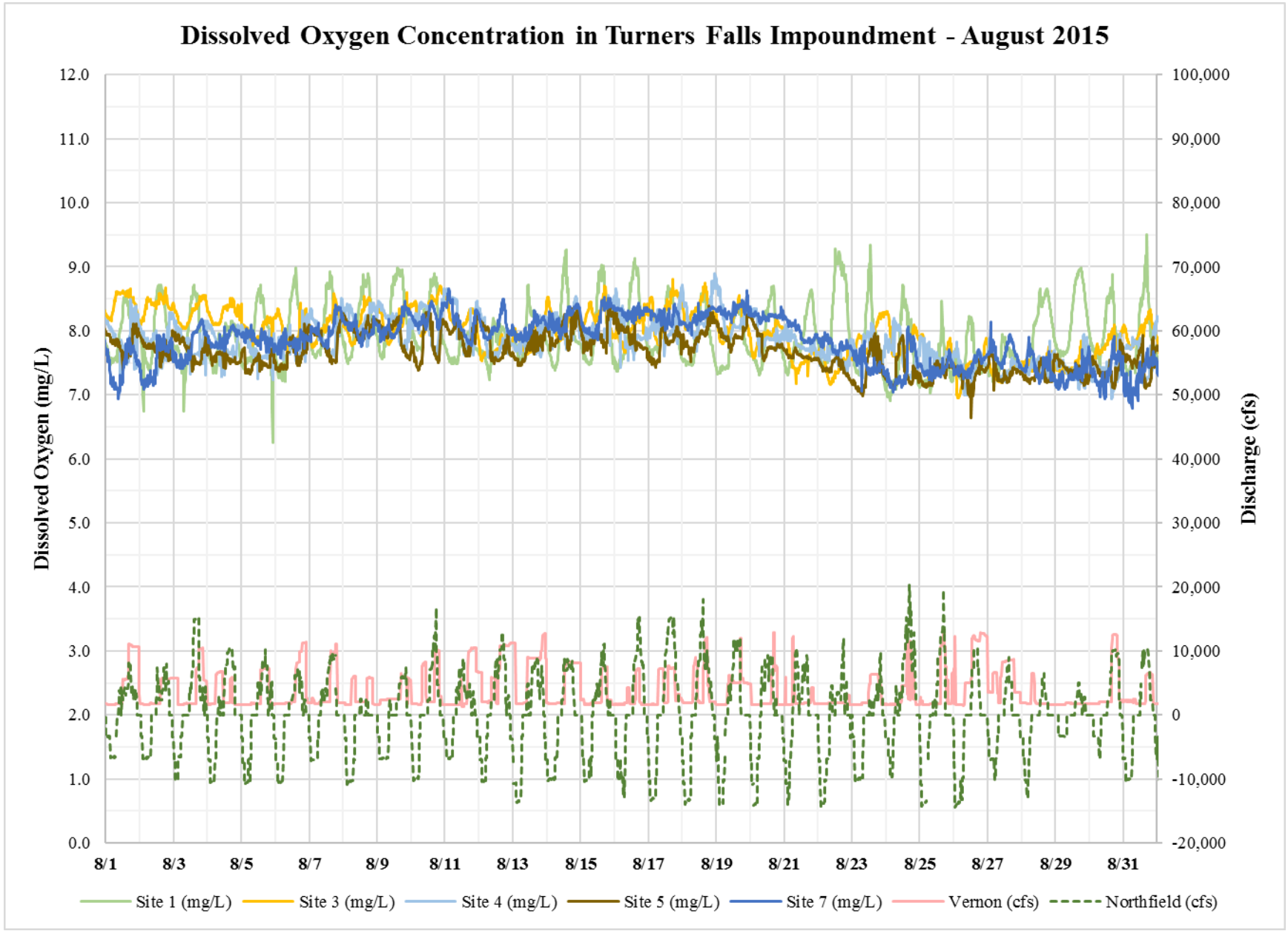
APPENDIX E- MONTHLY CHARTS OF DISSOLVED OXYGEN CONCENTRATION VERSUS FLOW

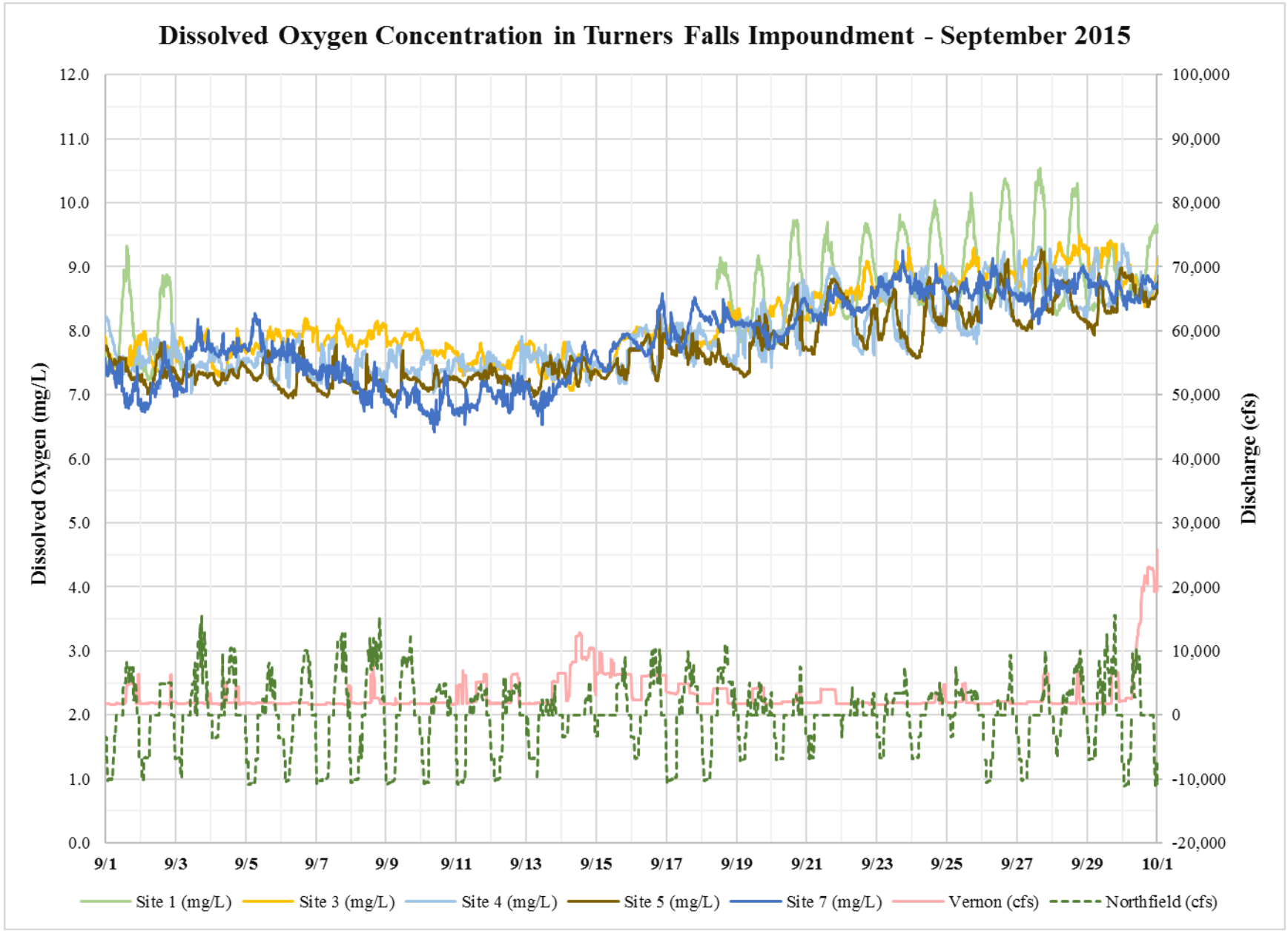
- **Sites 1-7: Turners Falls Impoundment**
- **Sites 8-11: Bypass Reach, Power Canal and below Cabot Station**

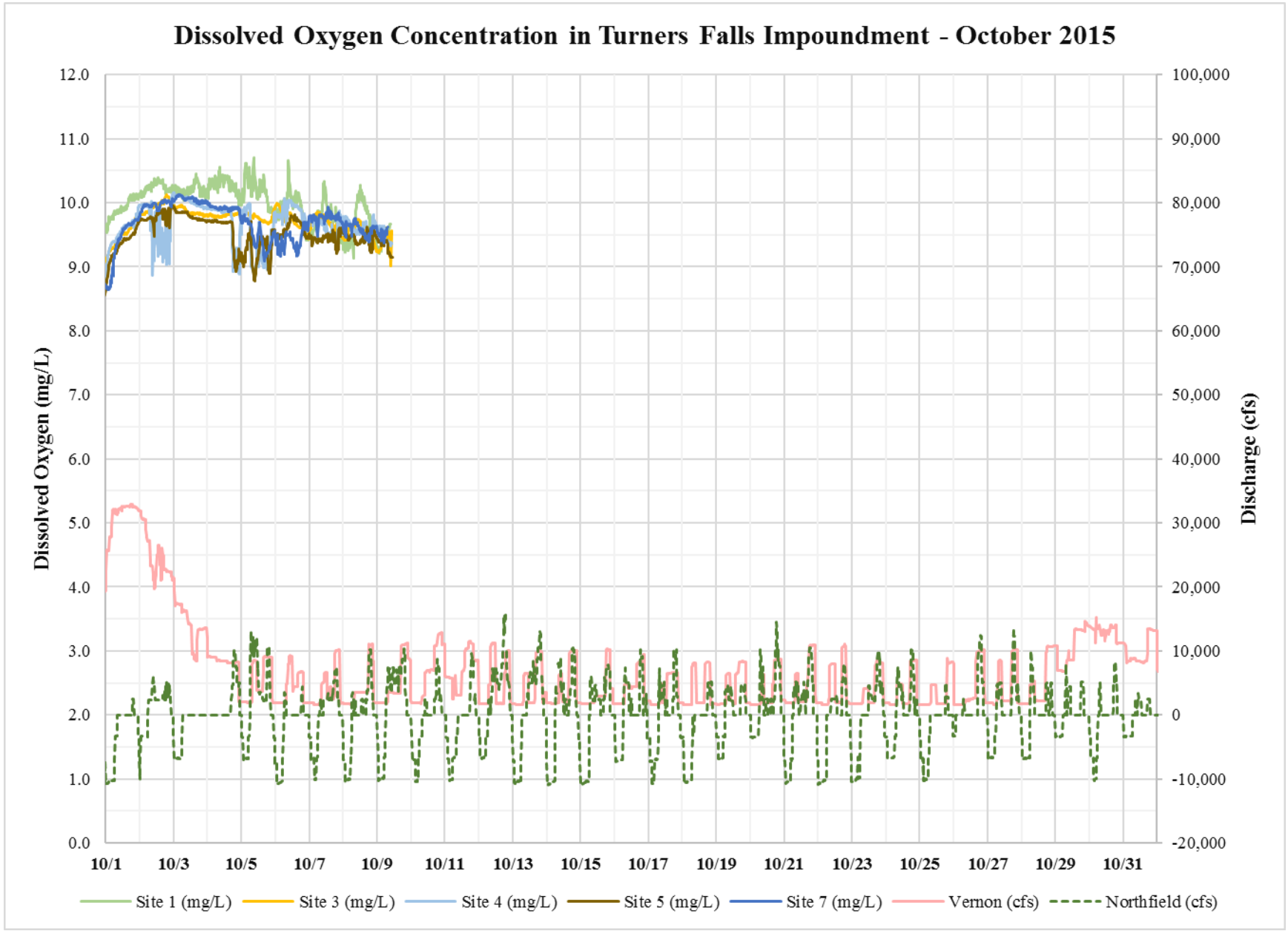

Dissolved Oxygen Concentration in Turners Falls Impoundment - May 2015
Dissolved Oxygen (mg/L)
Discharge (cfs)
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
5/1
5/3
5/5
5/7
5/9
5/11
5/13
5/15
5/17
5/19
5/21
5/23
5/25
5/27
5/29
5/31
Site 1 (mg/L)
Site 3 (mg/L)
Site 4 (mg/L)
Site 5 (mg/L)
Site 7 (mg/L)
Vernon (cfs)
Northfield (cfs)

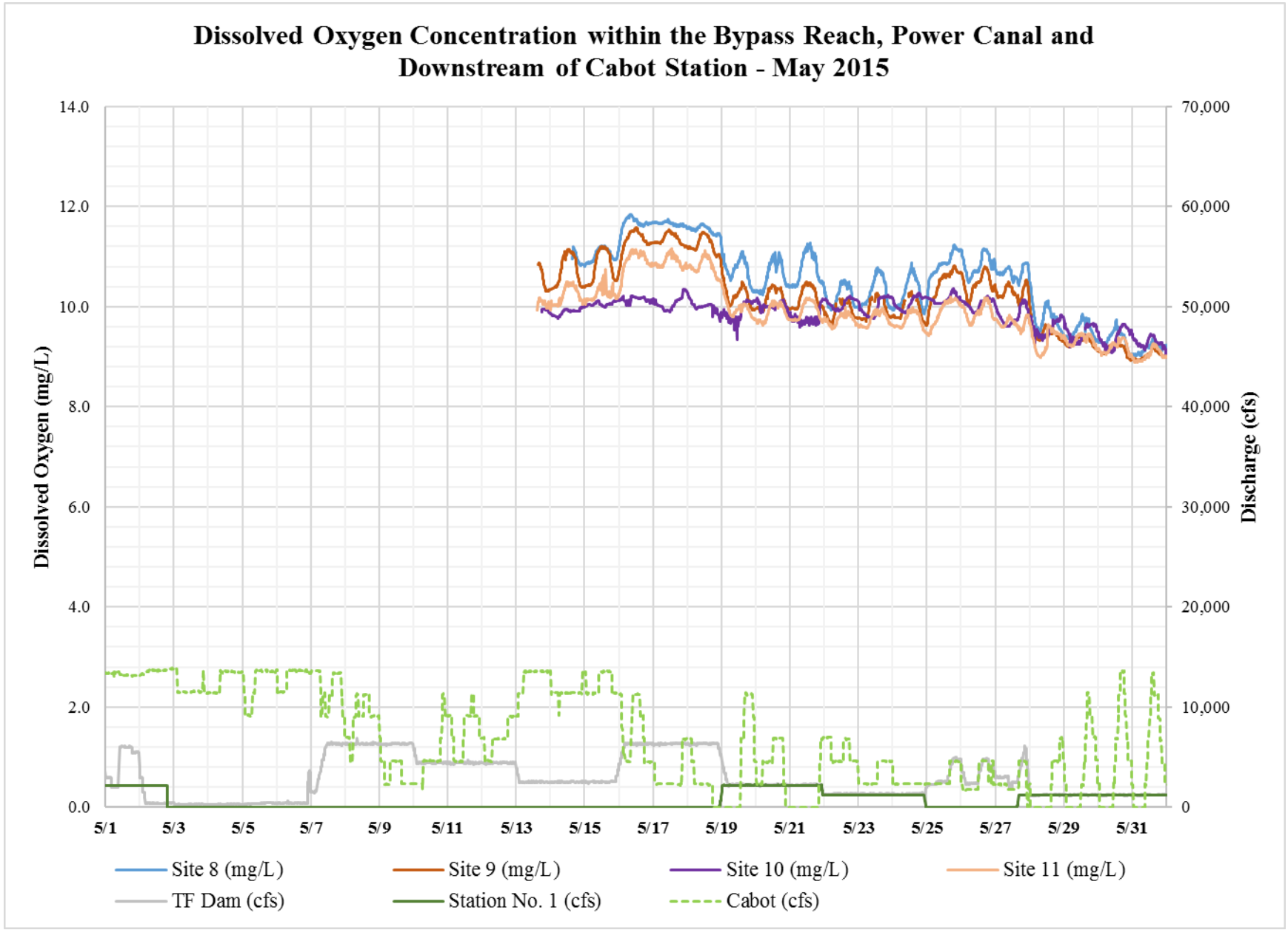

Dissolved Oxygen Concentration in Turners Falls Impoundment - June 2015
Dissolved Oxygen (mg/L)
Discharge (cfs)
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
6/1
6/3
6/5
6/7
6/9
6/11
6/13
6/15
6/17
6/19
6/21
6/23
6/25
6/27
6/29
7/1
Site 1 (mg/L)
Site 3 (mg/L)
Site 4 (mg/L)
Site 5 (mg/L)
Site 7 (mg/L)
Vernon (cfs)
Northfield (cfs)

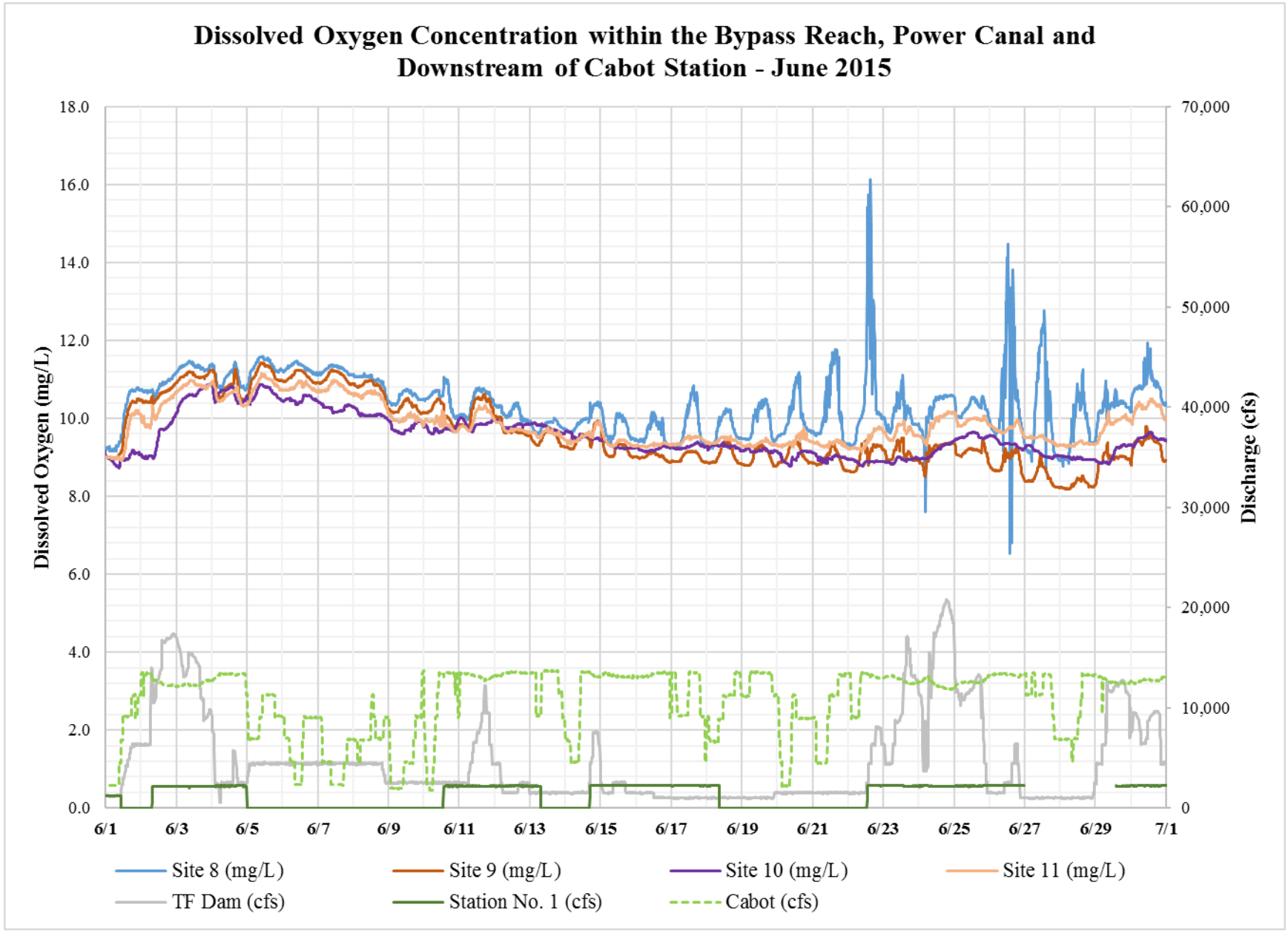

Dissolved Oxygen Concentration in Turners Falls Impoundment - July 2015
Dissolved Oxygen (mg/L)
Discharge (cfs)
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
7/1
7/3
7/5
7/7
7/9
7/11
7/13
7/15
7/17
7/19
7/21
7/23
7/25
7/27
7/29
7/31
Site 1 (mg/L)
Site 3 (mg/L)
Site 4 (mg/L)
Site 5 (mg/L)
Site 7 (mg/L)
Vernon (cfs)
Northfield (cfs)

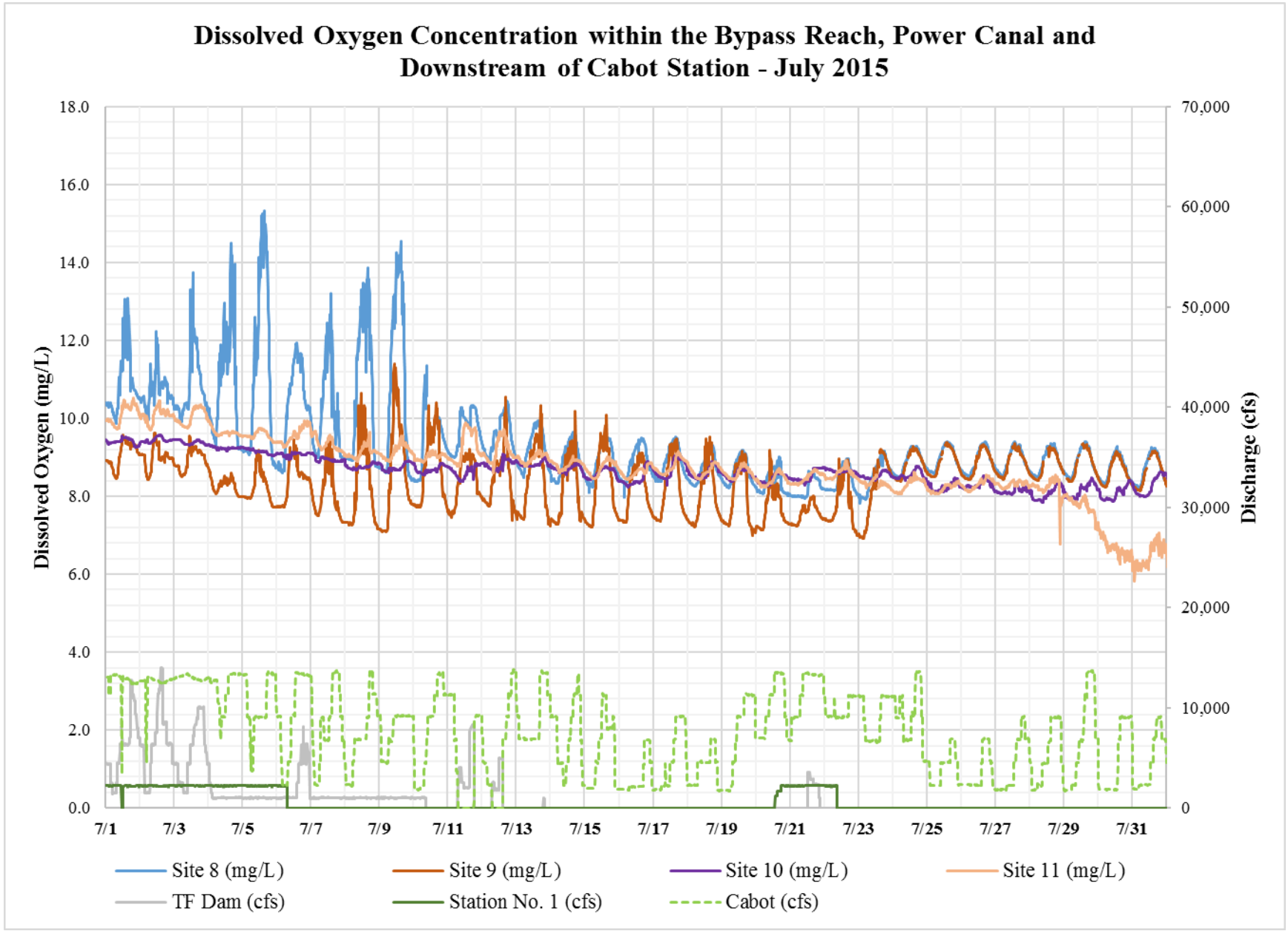

Dissolved Oxygen Concentration in Turners Falls Impoundment - August 2015
Dissolved Oxygen (mg/L)
Discharge (cfs)
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
8/1
8/3
8/5
8/7
8/9
8/11
8/13
8/15
8/17
8/19
8/21
8/23
8/25
8/27
8/29
8/31
Site 1 (mg/L)
Site 3 (mg/L)
Site 4 (mg/L)
Site 5 (mg/L)
Site 7 (mg/L)
Vernon (cfs)
Northfield (cfs)

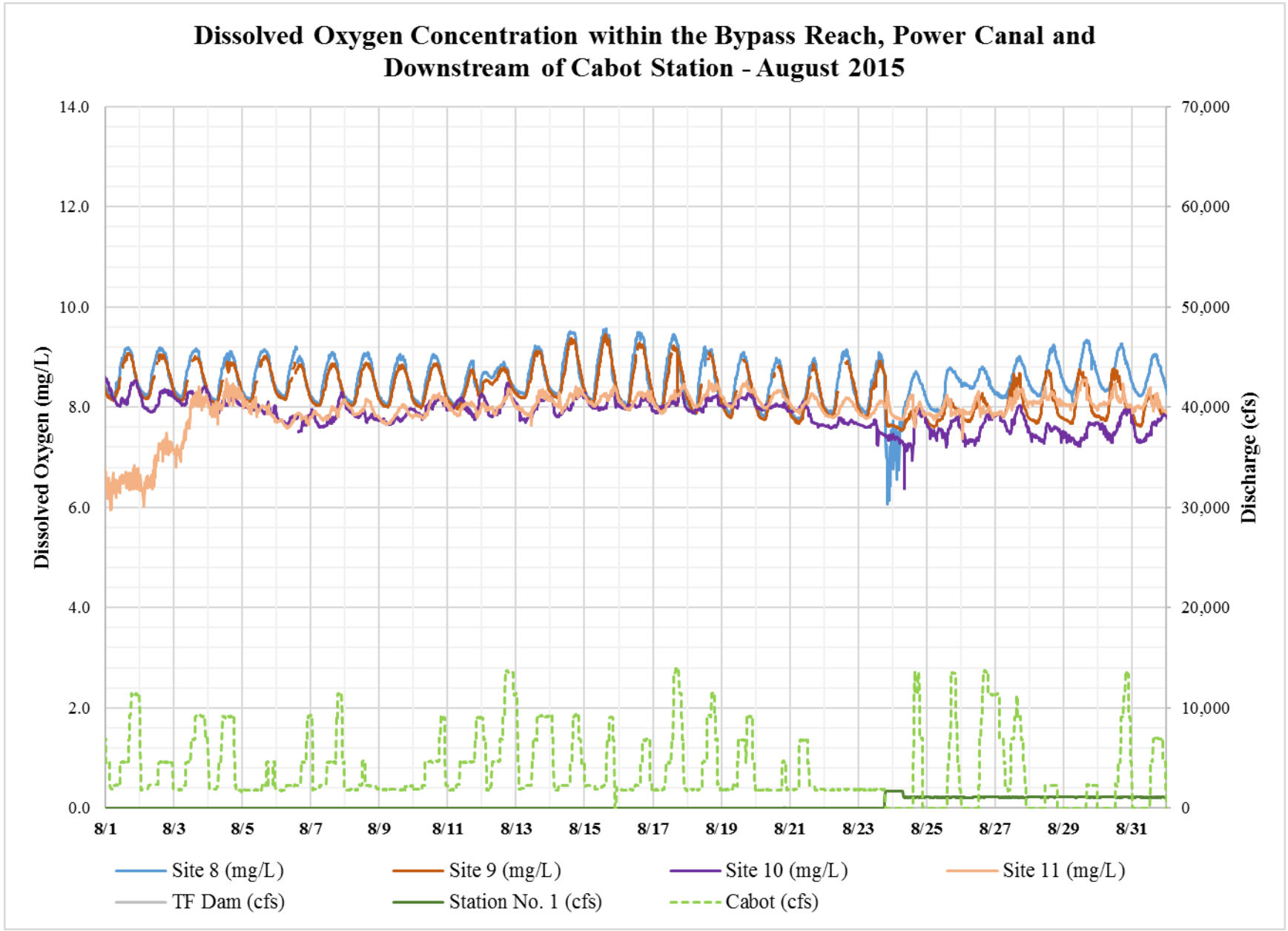

Dissolved Oxygen Concentration in Turners Falls Impoundment - September 2015
Dissolved Oxygen (mg/L)
Discharge (cfs)
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
9/1
9/3
9/5
9/7
9/9
9/11
9/13
9/15
9/17
9/19
9/21
9/23
9/25
9/27
9/29
10/1
Site 1 (mg/L)
Site 3 (mg/L)
Site 4 (mg/L)
Site 5 (mg/L)
Site 7 (mg/L)
Vernon (cfs)
Northfield (cfs)

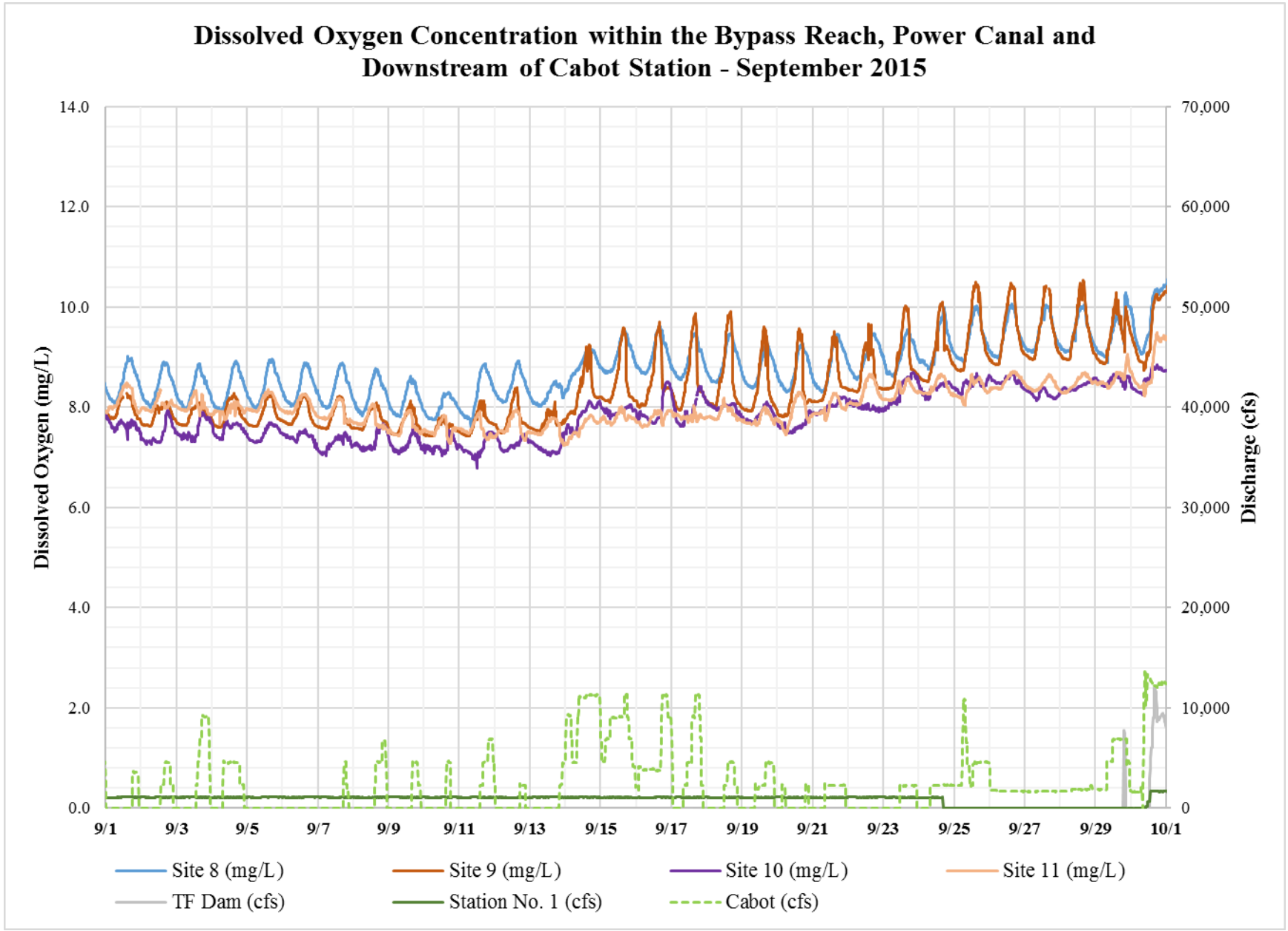

Dissolved Oxygen Concentration in Turners Falls Impoundment - October 2015
Dissolved Oxygen (mg/L)
Discharge (cfs)
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
10/1
10/3
10/5
10/7
10/9
10/11
10/13
10/15
10/17
10/19
10/21
10/23
10/25
10/27
10/29
10/31
Site 1 (mg/L)
Site 3 (mg/L)
Site 4 (mg/L)
Site 5 (mg/L)
Site 7 (mg/L)
Vernon (cfs)
Northfield (cfs)

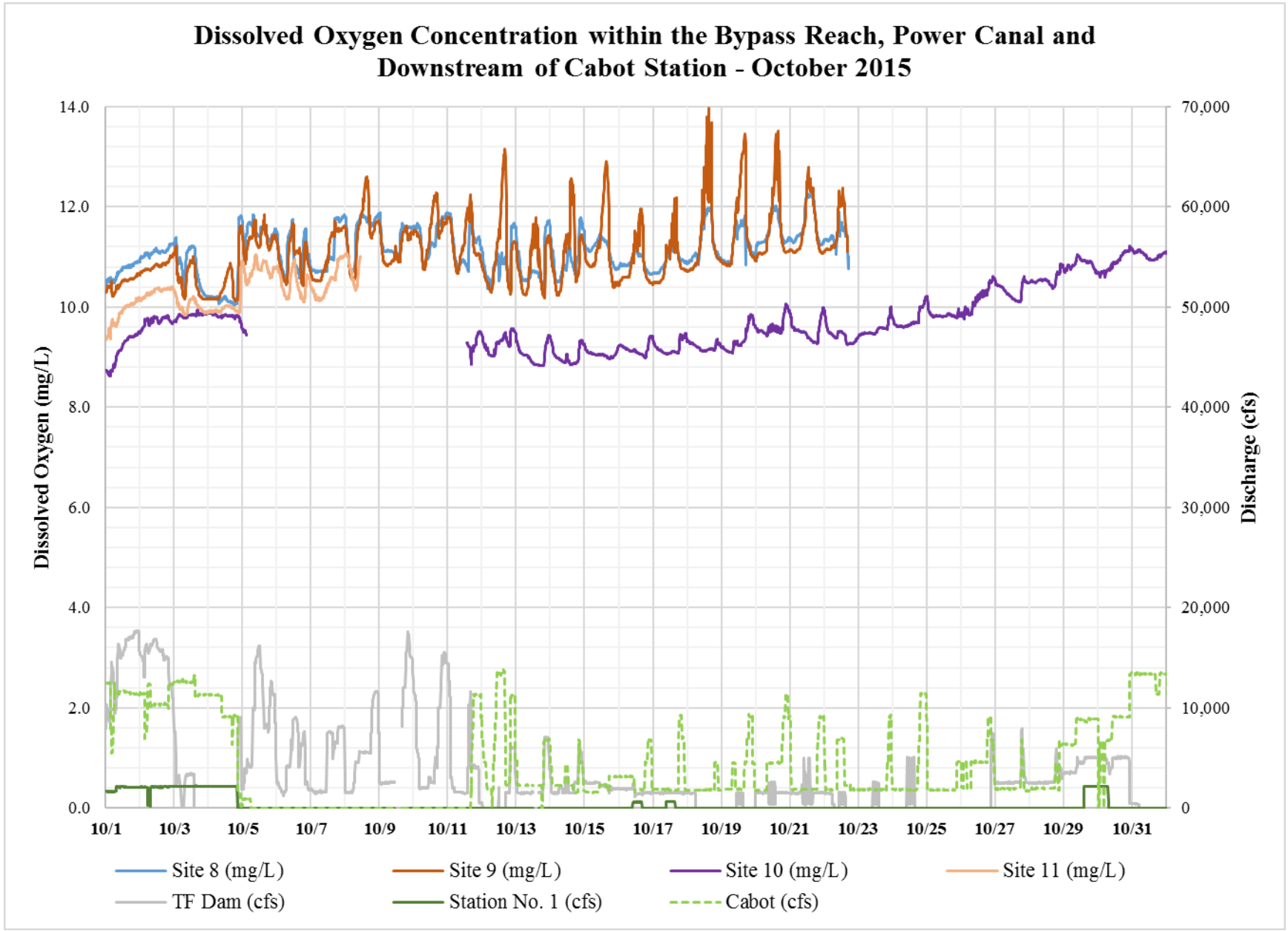

Dissolved Oxygen Concentration within the Bypass Reach, Power Canal and Downstream of Cabot Station - May 2015
Dissolved Oxygen (mg/L)
Discharge (cfs)
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
5/1
5/3
5/5
5/7
5/9
5/11
5/13
5/15
5/17
5/19
5/21
5/23
5/25
5/27
5/29
5/31
Site 8 (mg/L)
Site 9 (mg/L)
Site 10 (mg/L)
Site 11 (mg/L)
TF Dam (cfs)
Station No. 1 (cfs)
Cabot (cfs)


Dissolved Oxygen Concentration within the Bypass Reach, Power Canal and Downstream of Cabot Station - June 2015
Dissolved Oxygen (mg/L)
Discharge (cfs)
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
6/1
6/3
6/5
6/7
6/9
6/11
6/13
6/15
6/17
6/19
6/21
6/23
6/25
6/27
6/29
7/1
Site 8 (mg/L)
Site 9 (mg/L)
Site 10 (mg/L)
Site 11 (mg/L)
TF Dam (cfs)
Station No. 1 (cfs)
Cabot (cfs)


Dissolved Oxygen Concentration within the Bypass Reach, Power Canal and Downstream of Cabot Station - July 2015
Dissolved Oxygen (mg/L)
Discharge (cfs)
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
7/1
7/3
7/5
7/7
7/9
7/11
7/13
7/15
7/17
7/19
7/21
7/23
7/25
7/27
7/29
7/31
Site 8 (mg/L)
Site 9 (mg/L)
Site 10 (mg/L)
Site 11 (mg/L)
TF Dam (cfs)
Station No. 1 (cfs)
Cabot (cfs)

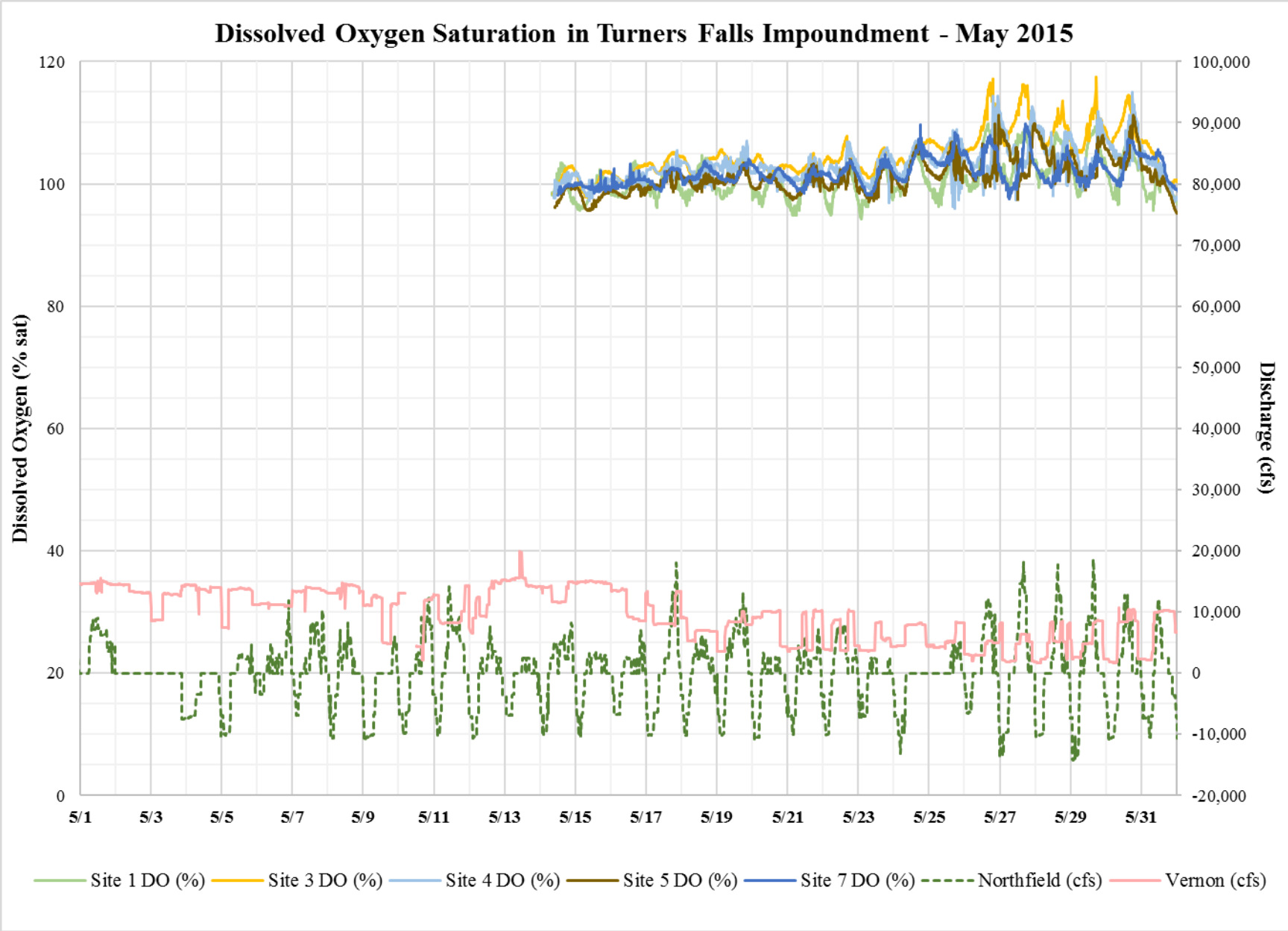

Dissolved Oxygen Concentration within the Bypass Reach, Power Canal and Downstream of Cabot Station - August 2015
Dissolved Oxygen (mg/L)
Discharge (cfs)
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
8/1
8/3
8/5
8/7
8/9
8/11
8/13
8/15
8/17
8/19
8/21
8/23
8/25
8/27
8/29
8/31
Site 8 (mg/L)
Site 9 (mg/L)
Site 10 (mg/L)
Site 11 (mg/L)
TF Dam (cfs)
Station No. 1 (cfs)
Cabot (cfs)

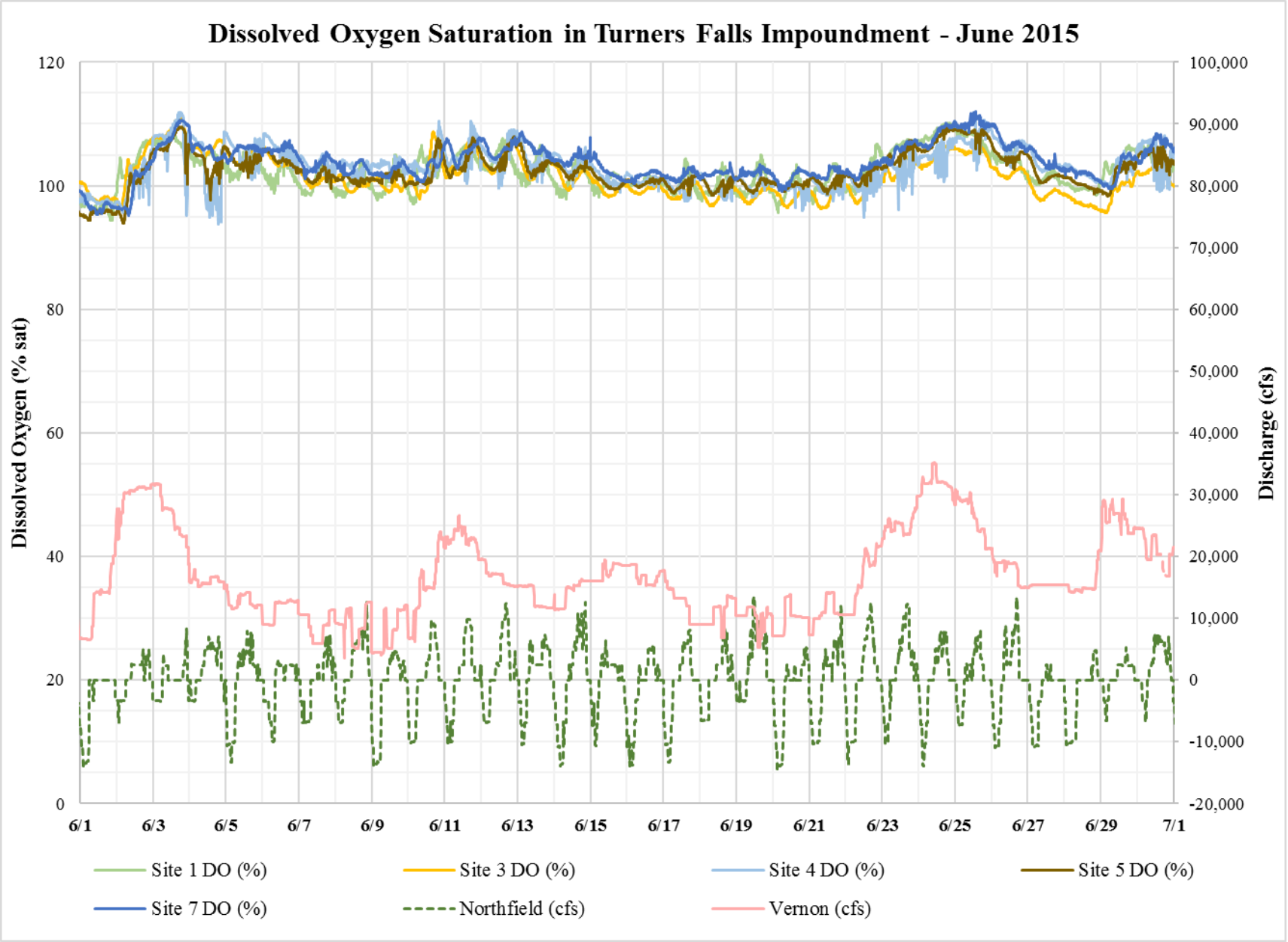

Dissolved Oxygen Concentration within the Bypass Reach, Power Canal and Downstream of Cabot Station - September 2015
Dissolved Oxygen (mg/L)
Discharge (cfs)
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
9/1
9/3
9/5
9/7
9/9
9/11
9/13
9/15
9/17
9/19
9/21
9/23
9/25
9/27
9/29
10/1
Site 8 (mg/L)
Site 9 (mg/L)
Site 10 (mg/L)
Site 11 (mg/L)
TF Dam (cfs)
Station No. 1 (cfs)
Cabot (cfs)

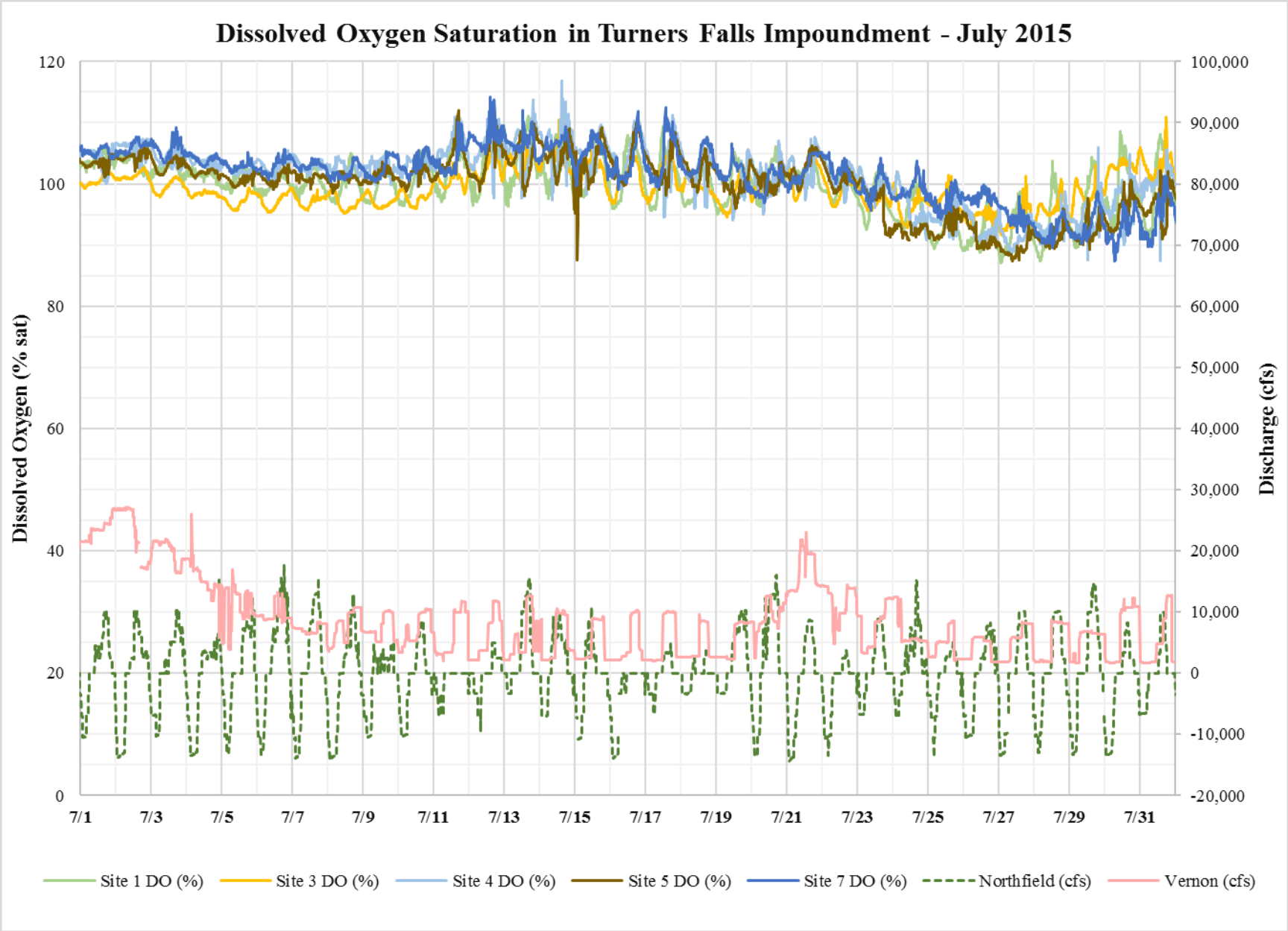

Dissolved Oxygen Concentration within the Bypass Reach, Power Canal and Downstream of Cabot Station - October 2015
Dissolved Oxygen (mg/L)
Discharge (cfs)
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
10/1
10/3
10/5
10/7
10/9
10/11
10/13
10/15
10/17
10/19
10/21
10/23
10/25
10/27
10/29
10/31
Site 8 (mg/L)
Site 9 (mg/L)
Site 10 (mg/L)
Site 11 (mg/L)
TF Dam (cfs)
Station No. 1 (cfs)
Cabot (cfs)

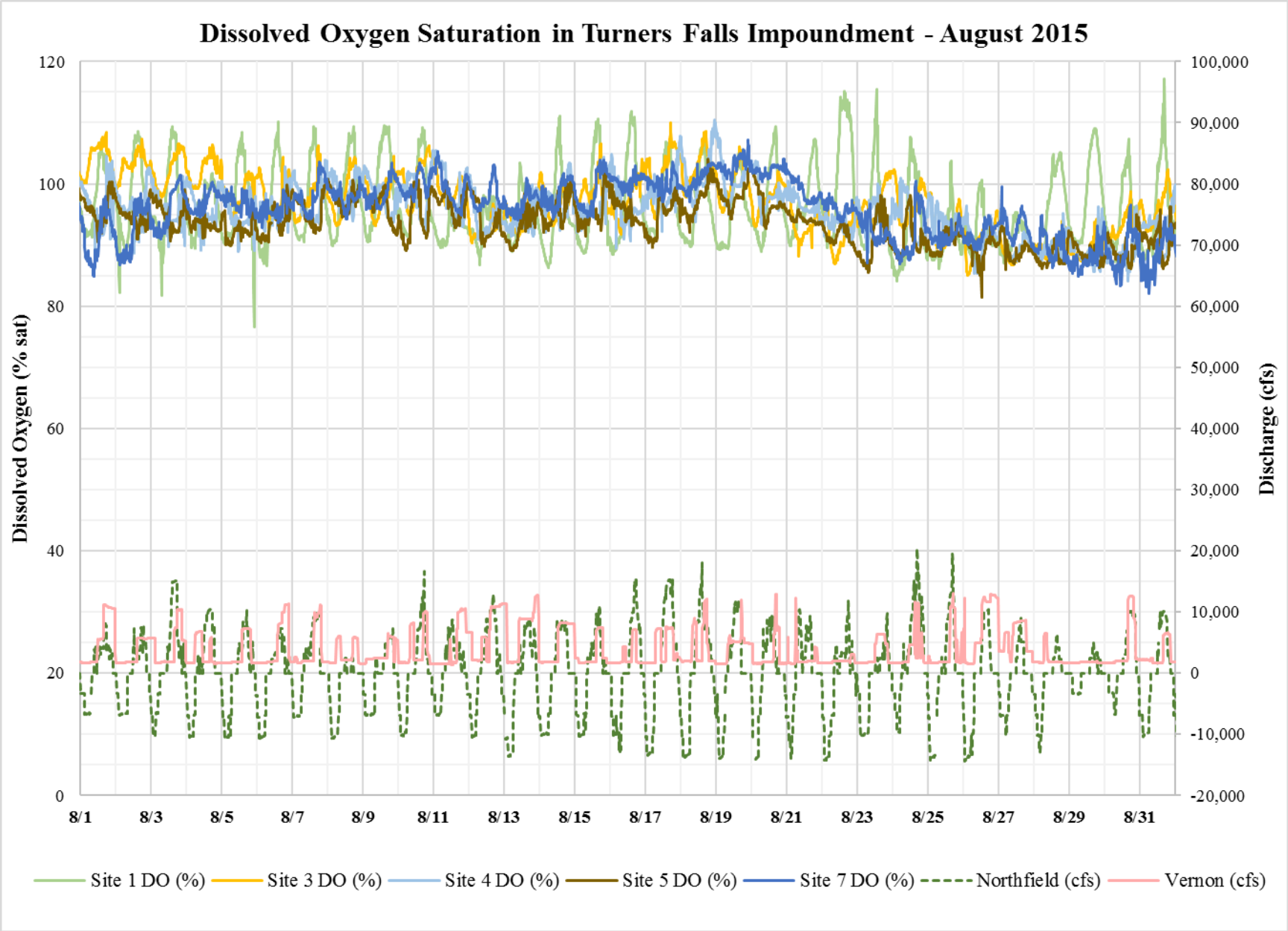
APPENDIX F- MONTHLY CHARTS OF DISSOLVED OXYGEN PERCENT SATURATION VERSUS FLOW

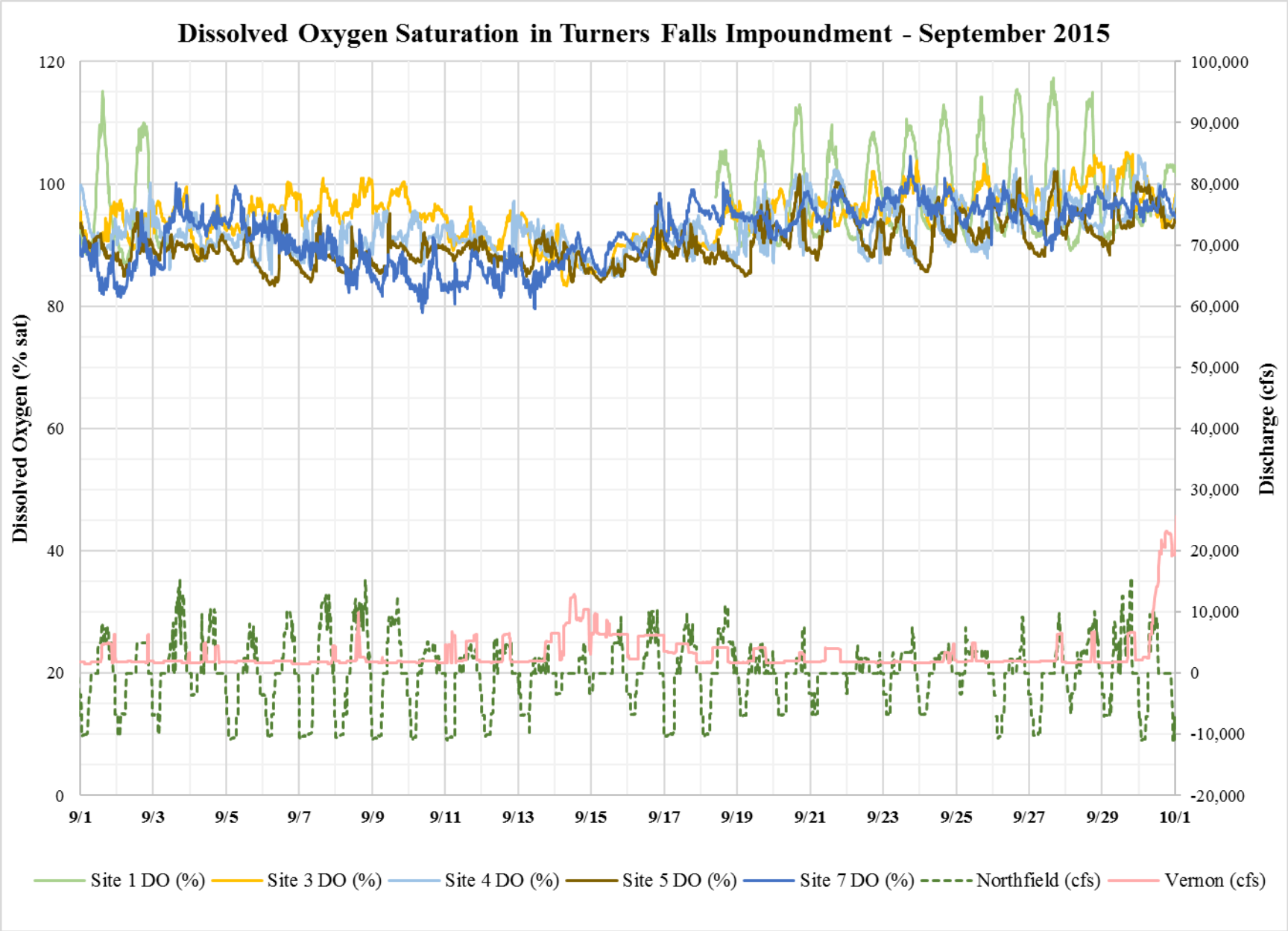
- **Sites 1-7: Turners Falls Impoundment**
- **Sites 8-11: Bypass Reach, Power Canal and below Cabot Station**

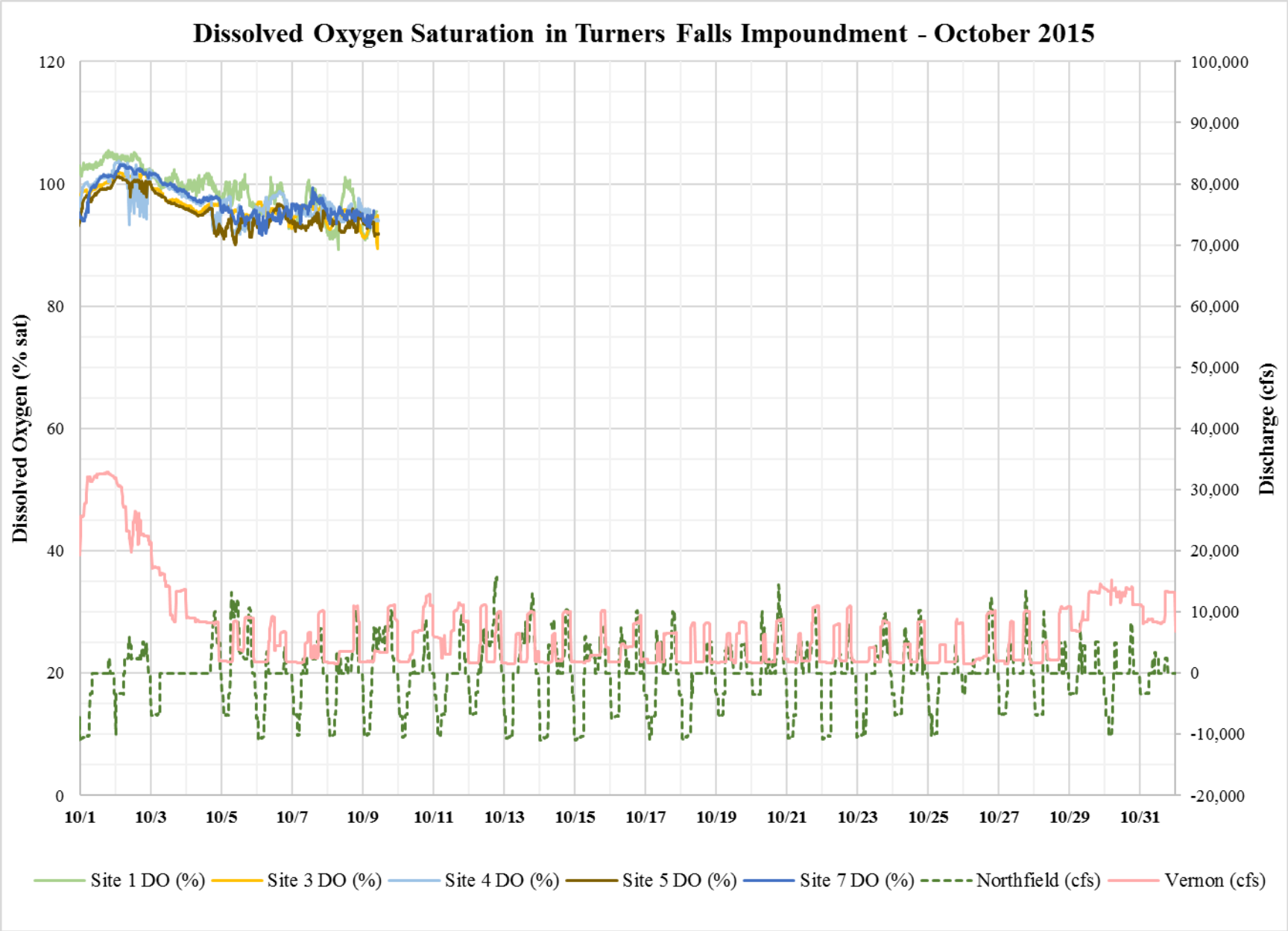

Dissolved Oxygen Saturation in Turners Falls Impoundment - May 2015
Dissolved Oxygen (% sat)
Discharge (cfs)
120
100
80
60
40
20
0
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
5/1
5/3
5/5
5/7
5/9
5/11
5/13
5/15
5/17
5/19
5/21
5/23
5/25
5/27
5/29
5/31
Site 1 DO (%)
Site 3 DO (%)
Site 4 DO (%)
Site 5 DO (%)
Site 7 DO (%)
Northfield (cfs)
Vernon (cfs)

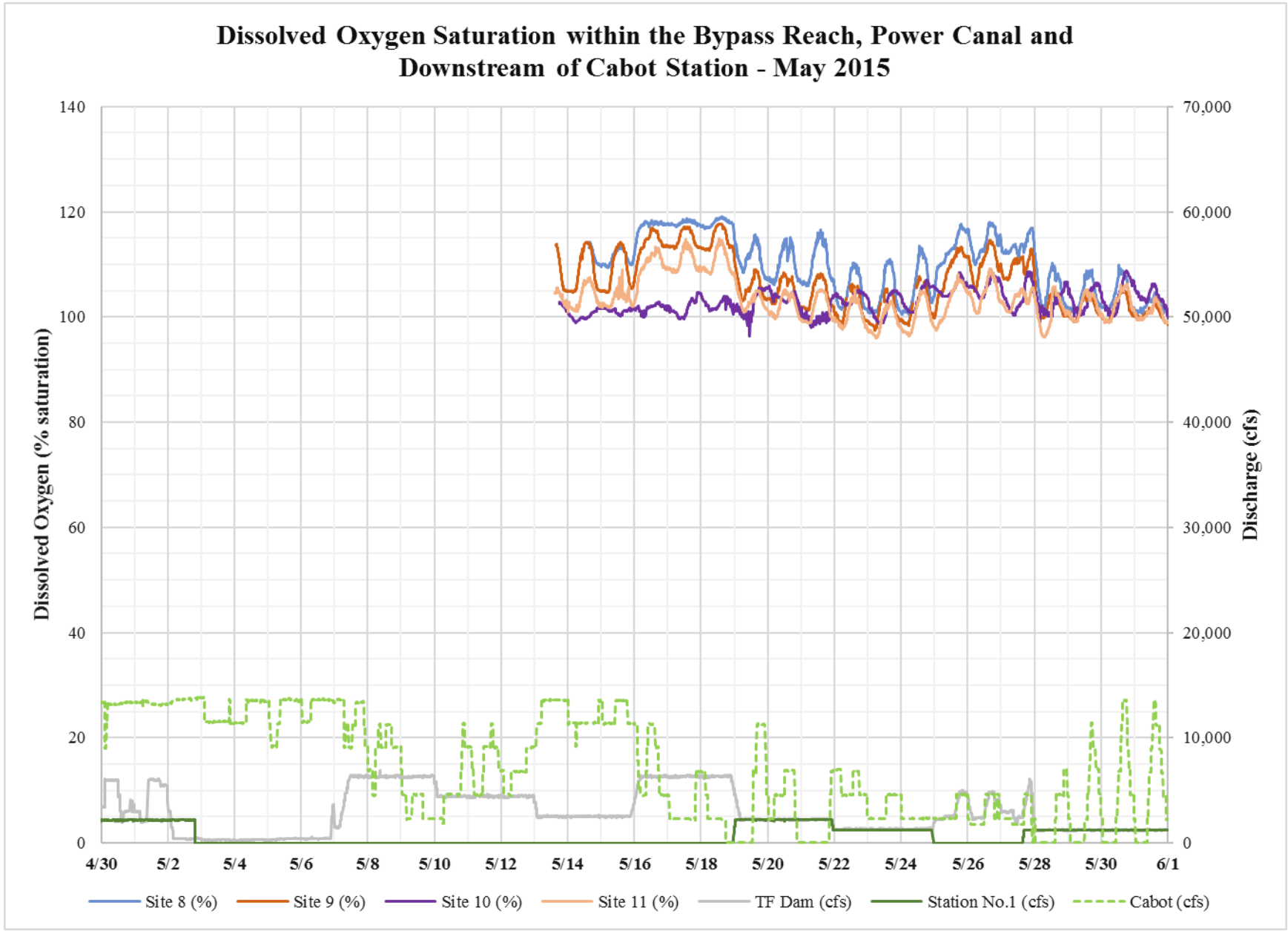

Dissolved Oxygen Saturation in Turners Falls Impoundment - June 2015
Dissolved Oxygen (% sat)
Discharge (cfs)
120
100
80
60
40
20
0
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
6/1
6/3
6/5
6/7
6/9
6/11
6/13
6/15
6/17
6/19
6/21
6/23
6/25
6/27
6/29
7/1
Site 1 DO (%)
Site 3 DO (%)
Site 4 DO (%)
Site 5 DO (%)
Site 7 DO (%)
Northfield (cfs)
Vernon (cfs)

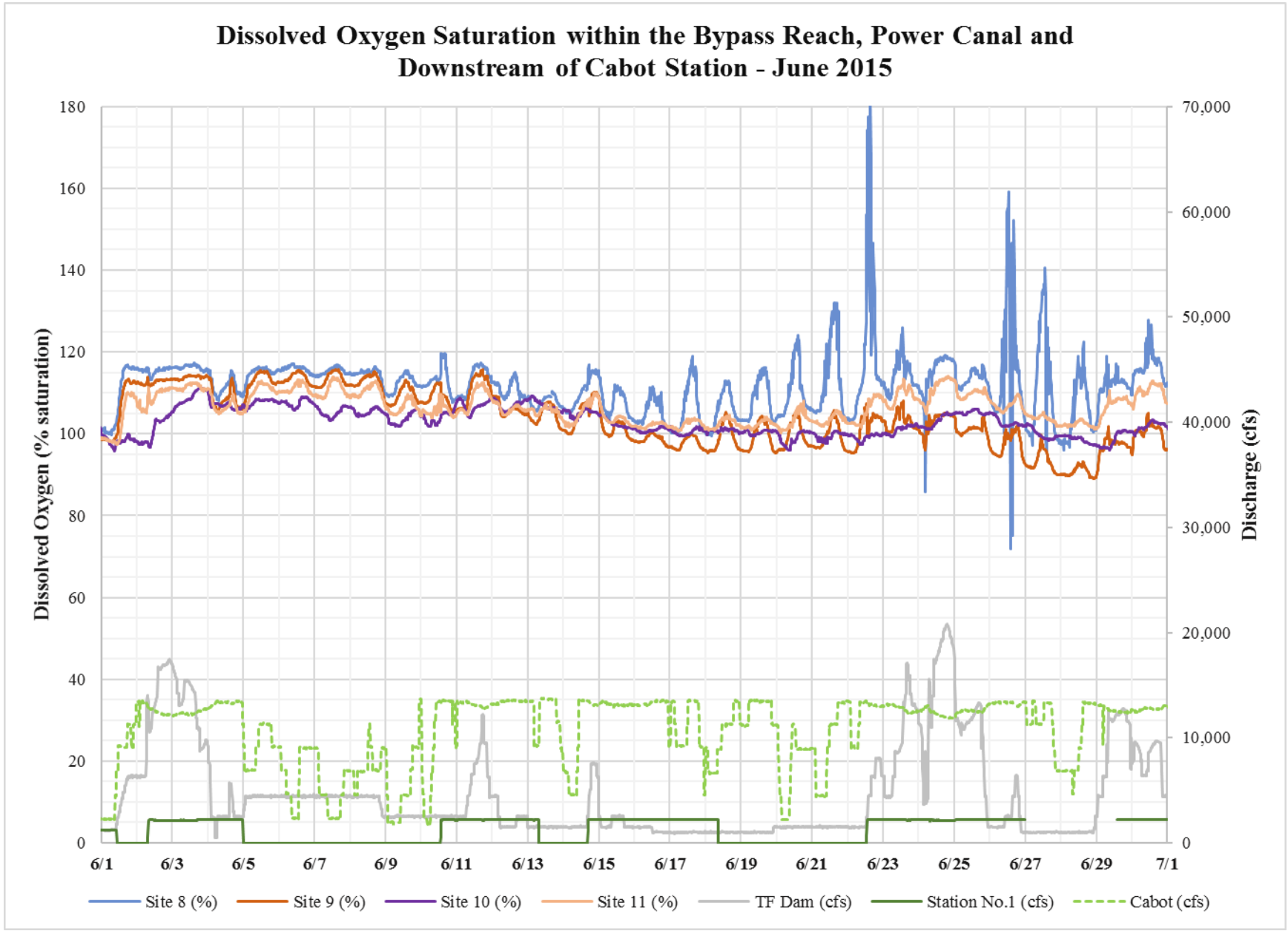

Dissolved Oxygen Saturation in Turners Falls Impoundment - July 2015
Dissolved Oxygen (% sat)
Discharge (cfs)
120
100
80
60
40
20
0
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
7/1
7/3
7/5
7/7
7/9
7/11
7/13
7/15
7/17
7/19
7/21
7/23
7/25
7/27
7/29
7/31
Site 1 DO (%)
Site 3 DO (%)
Site 4 DO (%)
Site 5 DO (%)
Site 7 DO (%)
Northfield (cfs)
Vernon (cfs)

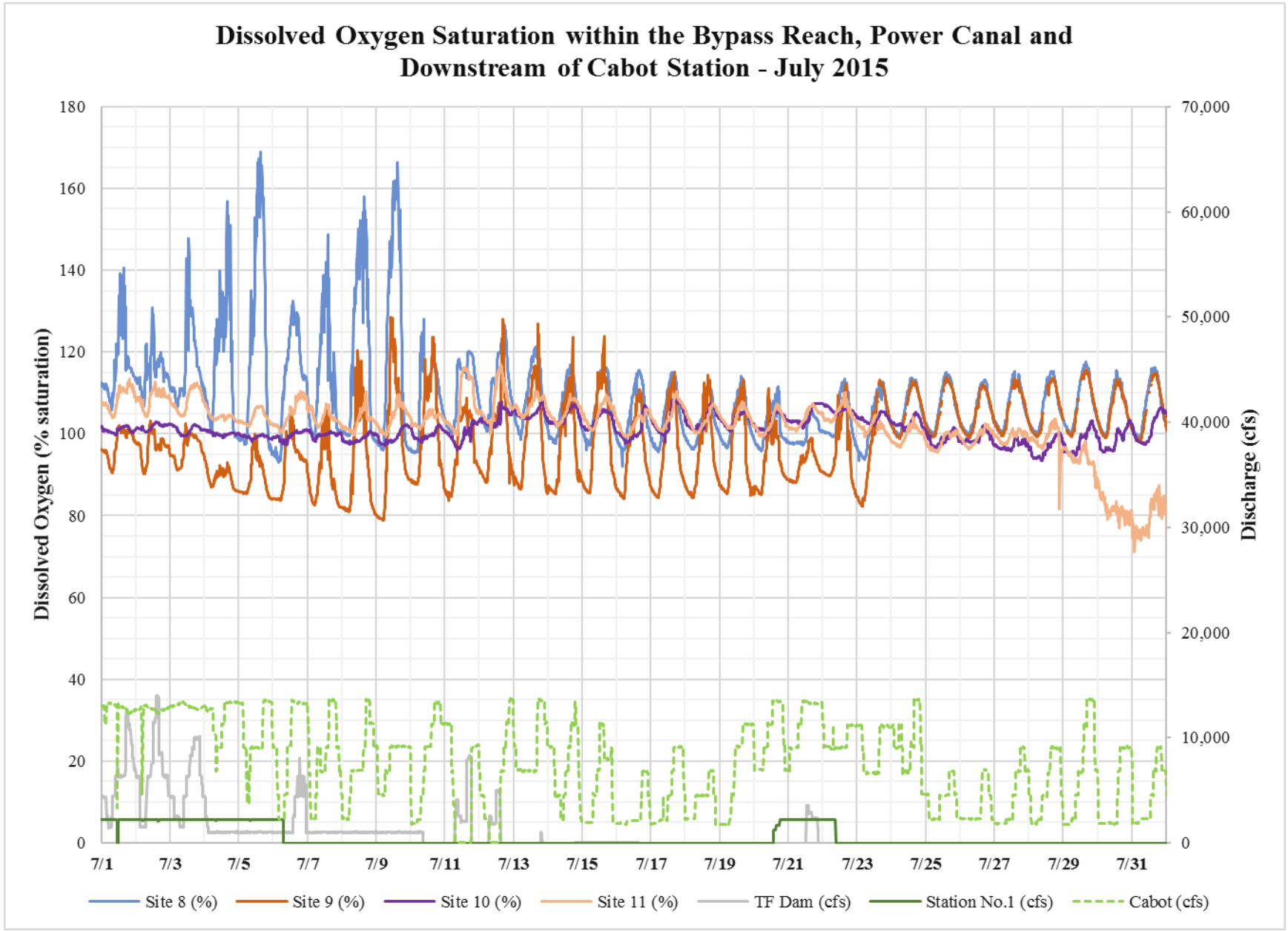

Dissolved Oxygen Saturation in Turners Falls Impoundment - August 2015
Dissolved Oxygen (% sat)
Discharge (cfs)
120
100
80
60
40
20
0
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
8/1
8/3
8/5
8/7
8/9
8/11
8/13
8/15
8/17
8/19
8/21
8/23
8/25
8/27
8/29
8/31
Site 1 DO (%)
Site 3 DO (%)
Site 4 DO (%)
Site 5 DO (%)
Site 7 DO (%)
Northfield (cfs)
Vernon (cfs)

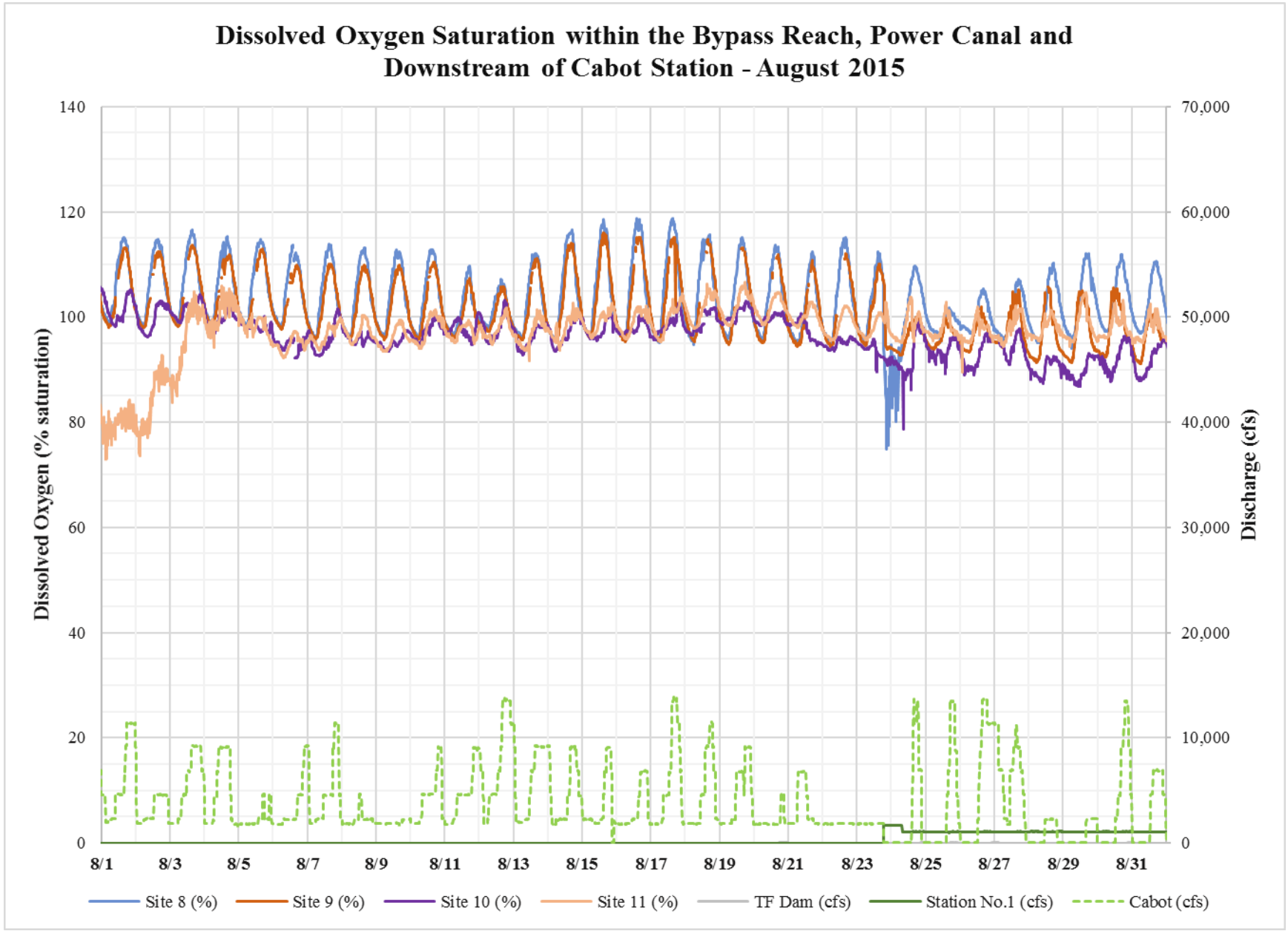

Dissolved Oxygen Saturation in Turners Falls Impoundment - September 2015
Dissolved Oxygen (% sat)
Discharge (cfs)
120
100
80
60
40
20
0
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
9/1
9/3
9/5
9/7
9/9
9/11
9/13
9/15
9/17
9/19
9/21
9/23
9/25
9/27
9/29
10/1
Site 1 DO (%)
Site 3 DO (%)
Site 4 DO (%)
Site 5 DO (%)
Site 7 DO (%)
Northfield (cfs)
Vernon (cfs)

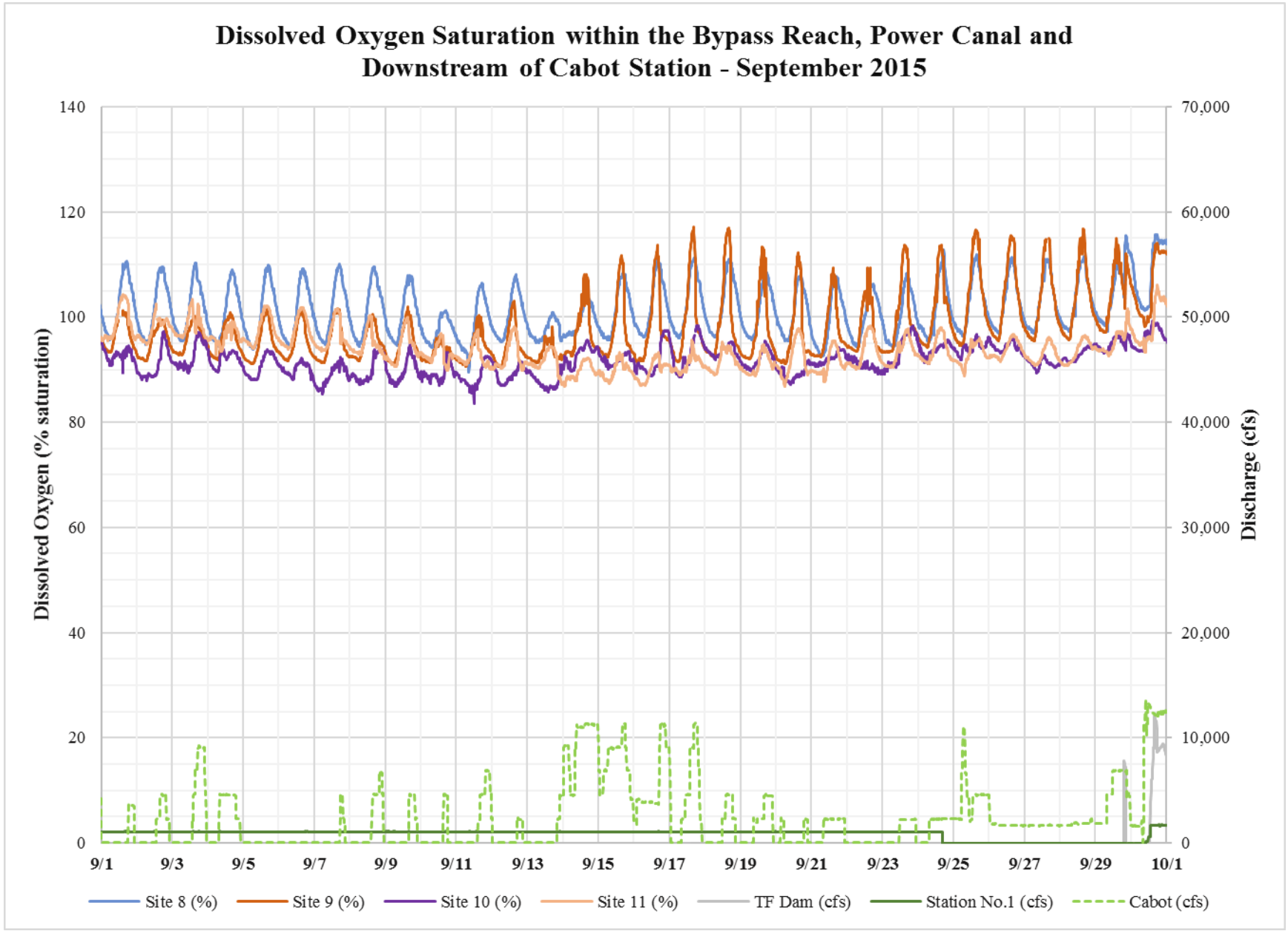

Dissolved Oxygen Saturation in Turners Falls Impoundment - October 2015
Dissolved Oxygen (% sat)
Discharge (cfs)
120
100
80
60
40
20
0
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
10/1
10/3
10/5
10/7
10/9
10/11
10/13
10/15
10/17
10/19
10/21
10/23
10/25
10/27
10/29
10/31
Site 1 DO (%)
Site 3 DO (%)
Site 4 DO (%)
Site 5 DO (%)
Site 7 DO (%)
Northfield (cfs)
Vernon (cfs)

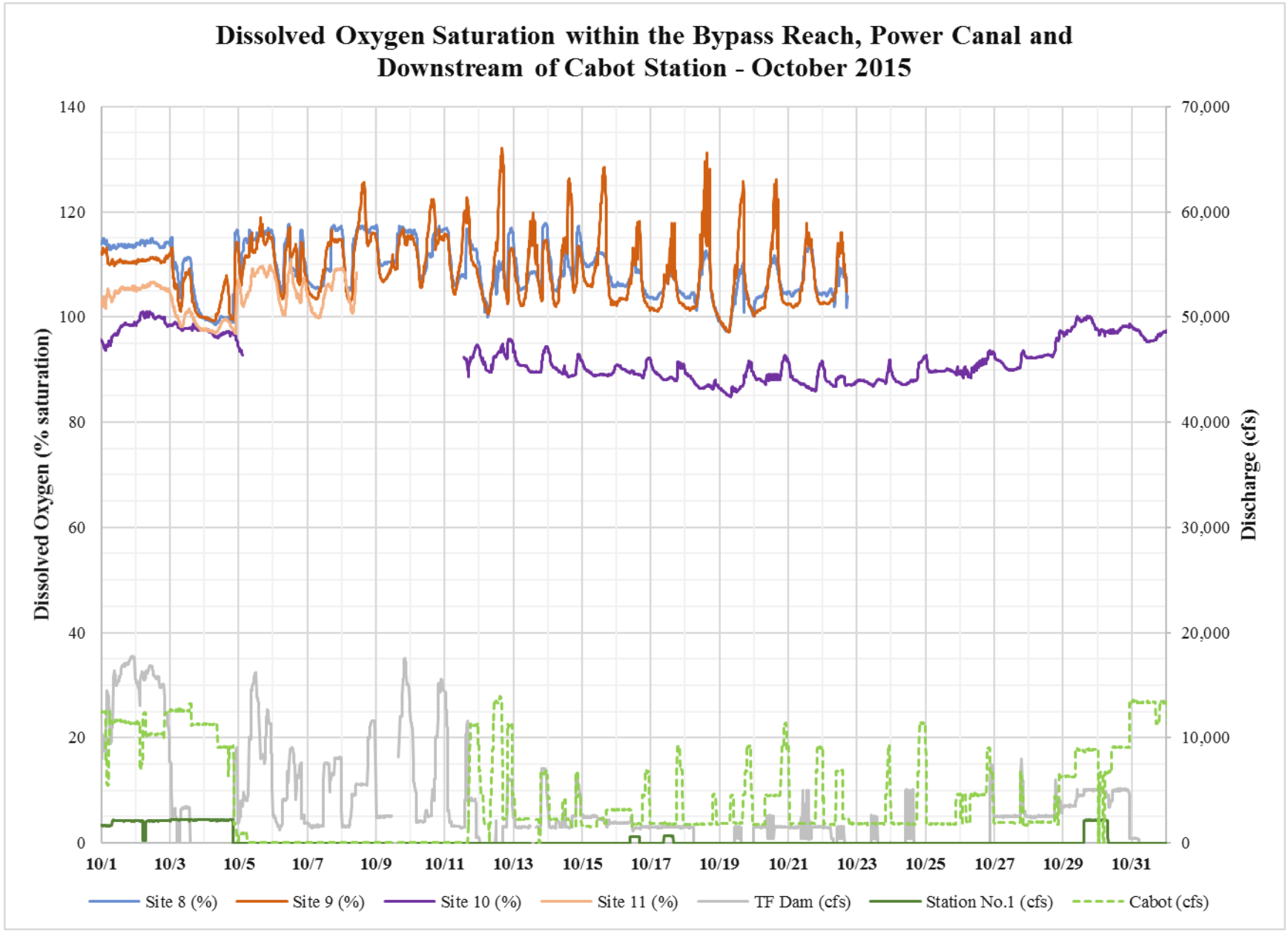

Dissolved Oxygen Saturation within the Bypass Reach, Power Canal and Downstream of Cabot Station - May 2015
Dissolved Oxygen (% saturation)
Discharge (cfs)
140
120
100
80
60
40
20
0
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
4/30
5/2
5/4
5/6
5/8
5/10
5/12
5/14
5/16
5/18
5/20
5/22
5/24
5/26
5/28
5/30
6/1
Site 8 (%)
Site 9 (%)
Site 10 (%)
Site 11 (%)
TF Dam (cfs)
Station No.1 (cfs)
Cabot (cfs)


Dissolved Oxygen Saturation within the Bypass Reach, Power Canal and Downstream of Cabot Station - June 2015
Dissolved Oxygen (% saturation)
Discharge (cfs)
180
160
140
120
100
80
60
40
20
0
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
6/1
6/3
6/5
6/7
6/9
6/11
6/13
6/15
6/17
6/19
6/21
6/23
6/25
6/27
6/29
7/1
Site 8 (%)
Site 9 (%)
Site 10 (%)
Site 11 (%)
TF Dam (cfs)
Station No.1 (cfs)
Cabot (cfs)


Dissolved Oxygen Saturation within the Bypass Reach, Power Canal and Downstream of Cabot Station - July 2015
Dissolved Oxygen (% saturation)
Discharge (cfs)
180
160
140
120
100
80
60
40
20
0
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
7/1
7/3
7/5
7/7
7/9
7/11
7/13
7/15
7/17
7/19
7/21
7/23
7/25
7/27
7/29
7/31
Site 8 (%)
Site 9 (%)
Site 10 (%)
Site 11 (%)
TF Dam (cfs)
Station No.1 (cfs)
Cabot (cfs)

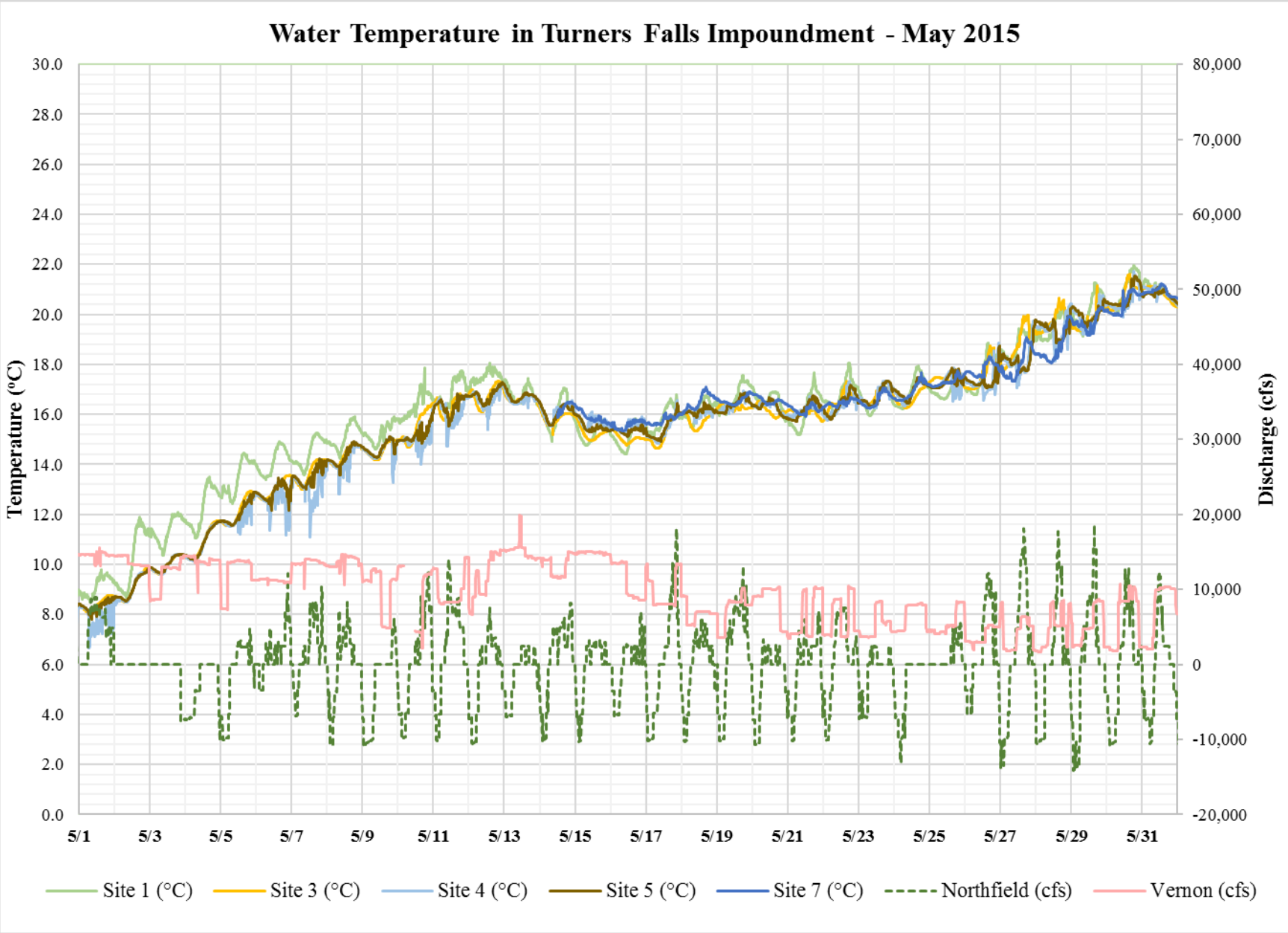

Dissolved Oxygen Saturation within the Bypass Reach, Power Canal and Downstream of Cabot Station - August 2015
Dissolved Oxygen (% saturation)
Discharge (cfs)
140
120
100
80
60
40
20
0
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
8/1
8/3
8/5
8/7
8/9
8/11
8/13
8/15
8/17
8/19
8/21
8/23
8/25
8/27
8/29
8/31
Site 8 (%)
Site 9 (%)
Site 10 (%)
Site 11 (%)
TF Dam (cfs)
Station No.1 (cfs)
Cabot (cfs)

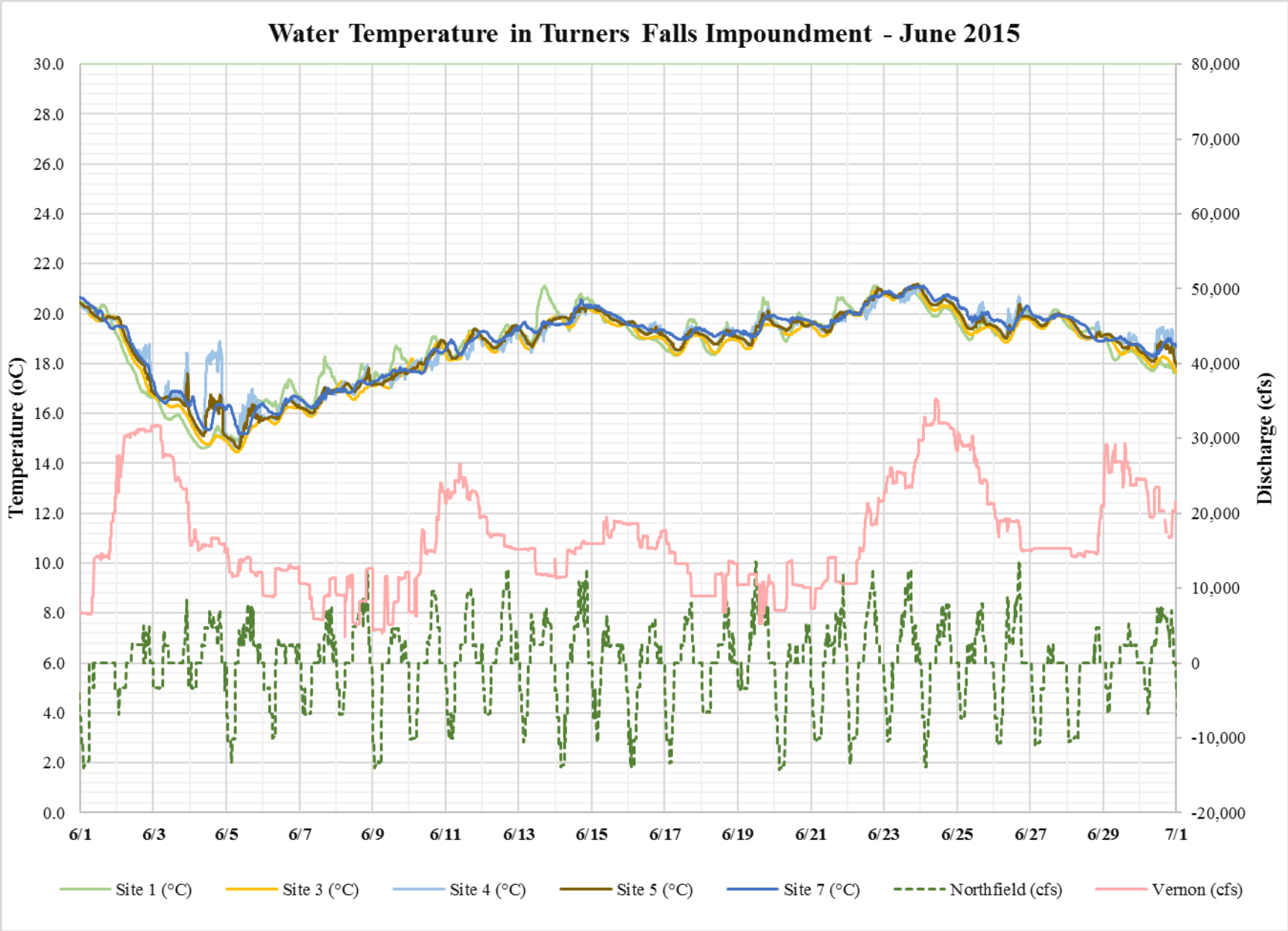

Dissolved Oxygen Saturation within the Bypass Reach, Power Canal and Downstream of Cabot Station - September 2015
Dissolved Oxygen (% saturation)
Discharge (cfs)
140
120
100
80
60
40
20
0
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
9/1
9/3
9/5
9/7
9/9
9/11
9/13
9/15
9/17
9/19
9/21
9/23
9/25
9/27
9/29
10/1
Site 8 (%)
Site 9 (%)
Site 10 (%)
Site 11 (%)
TF Dam (cfs)
Station No.1 (cfs)
Cabot (cfs)

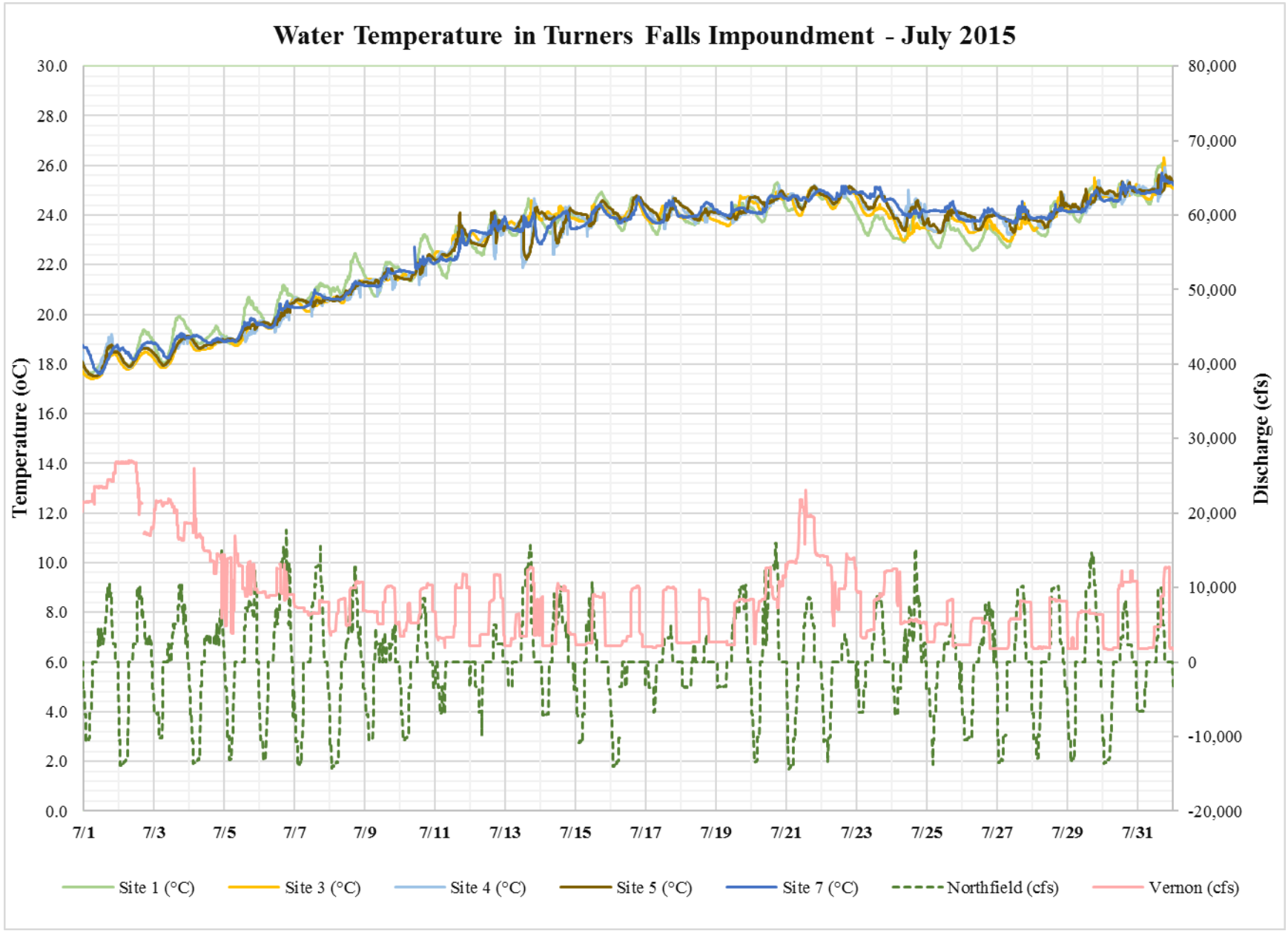

Dissolved Oxygen Saturation within the Bypass Reach, Power Canal and Downstream of Cabot Station - October 2015
Dissolved Oxygen (% saturation)
Discharge (cfs)
140
120
100
80
60
40
20
0
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
10/1
10/3
10/5
10/7
10/9
10/11
10/13
10/15
10/17
10/19
10/21
10/23
10/25
10/27
10/29
10/31
Site 8 (%)
Site 9 (%)
Site 10 (%)
Site 11 (%)
TF Dam (cfs)
Station No.1 (cfs)
Cabot (cfs)

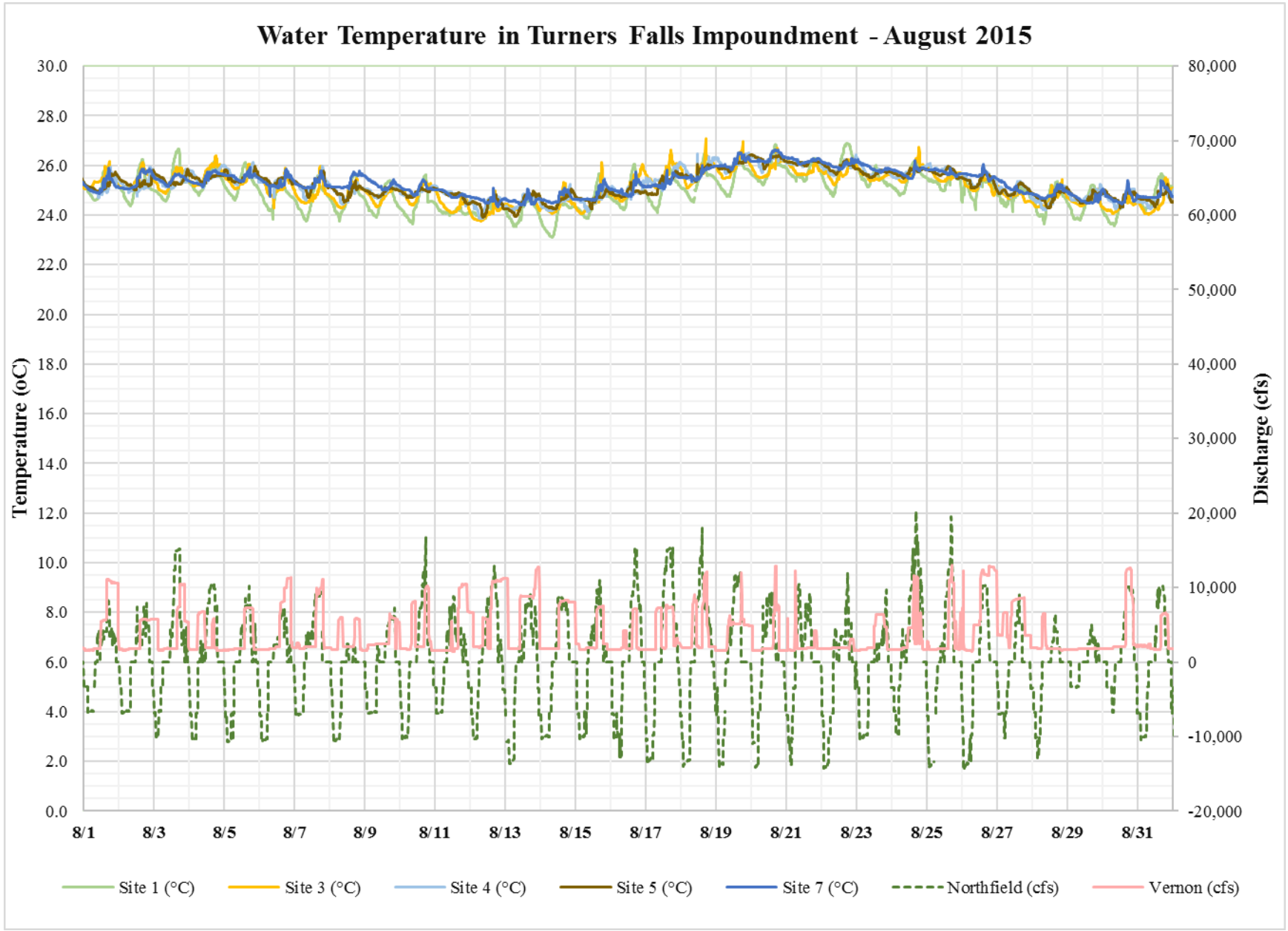
APPENDIX G- MONTHLY CHARTS OF WATER TEMPERATURE VERSUS FLOW

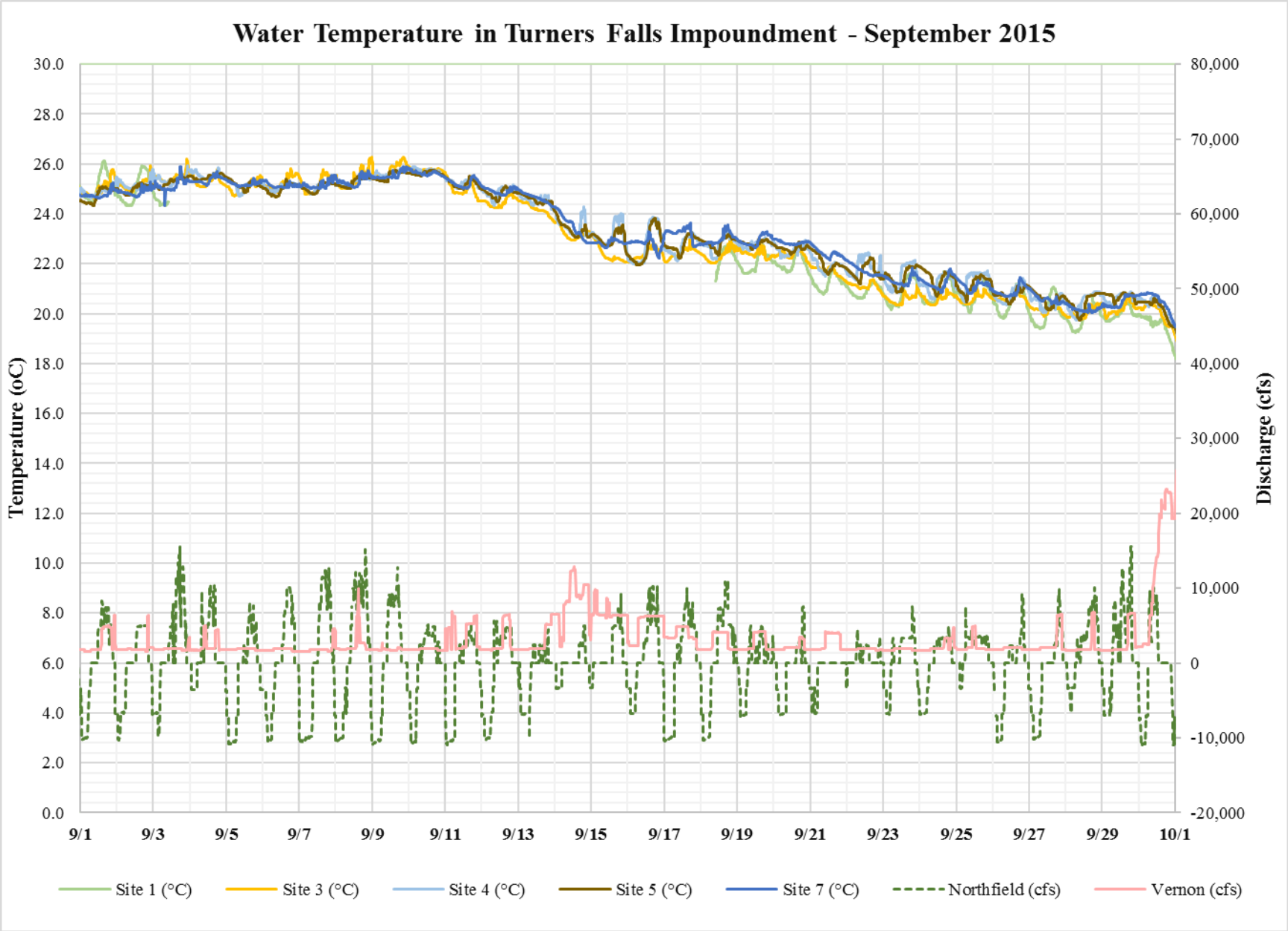
- **Sites 1-7: Turners Falls Impoundment**
- **Sites 8-11: Bypass Reach, Power Canal and below Cabot Station**
- **Sites 11-18: Downstream of Cabot Station to Holyoke Dam**

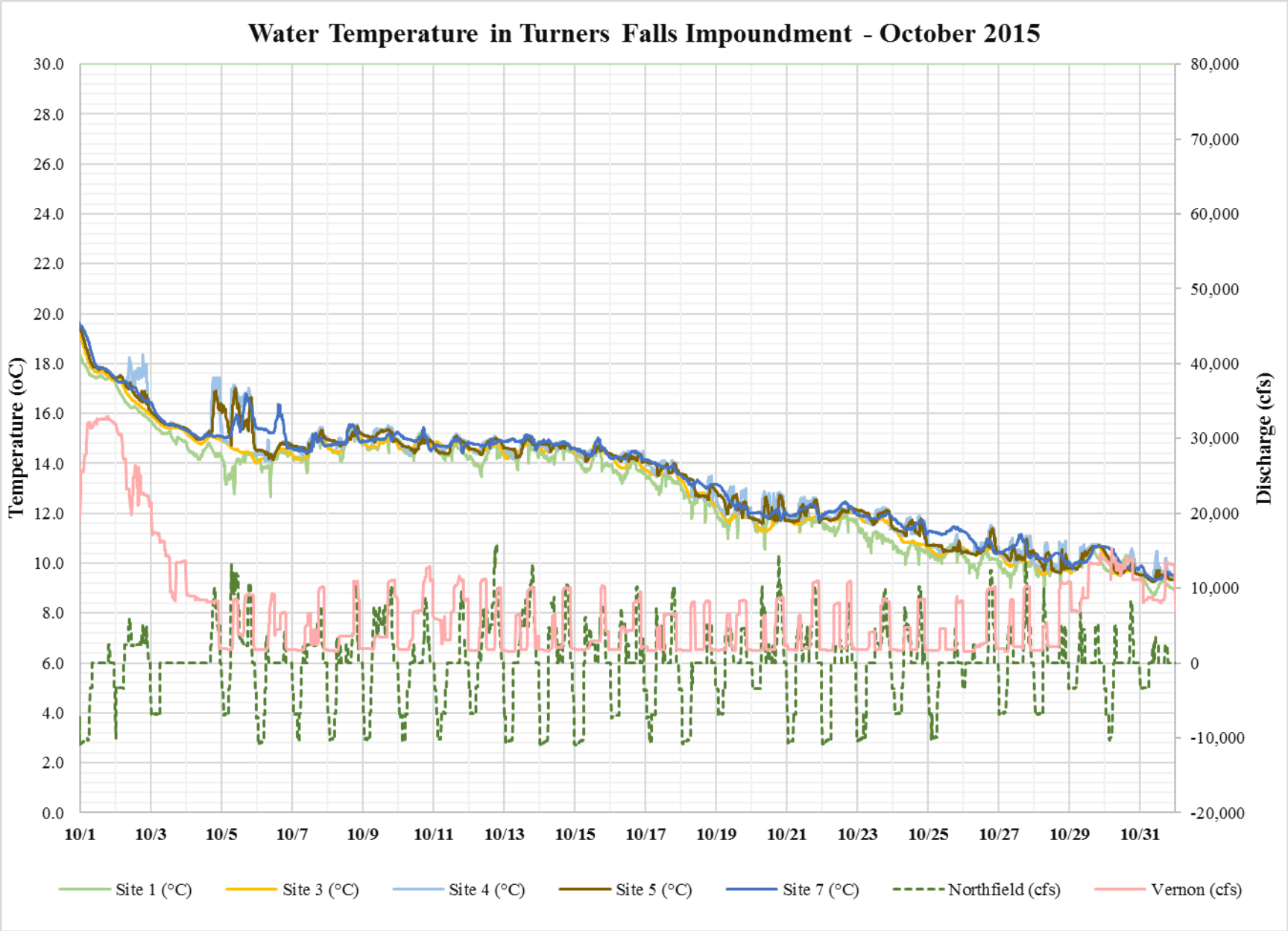

Water Temperature in Turners Falls Impoundment - May 2015
Temperature (°C)
Discharge (cfs)
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
5/1
5/3
5/5
5/7
5/9
5/11
5/13
5/15
5/17
5/19
5/21
5/23
5/25
5/27
5/29
5/31
Site 1 (°C)
Site 3 (°C)
Site 4 (°C)
Site 5 (°C)
Site 7 (°C)
Northfield (cfs)
Vernon (cfs)

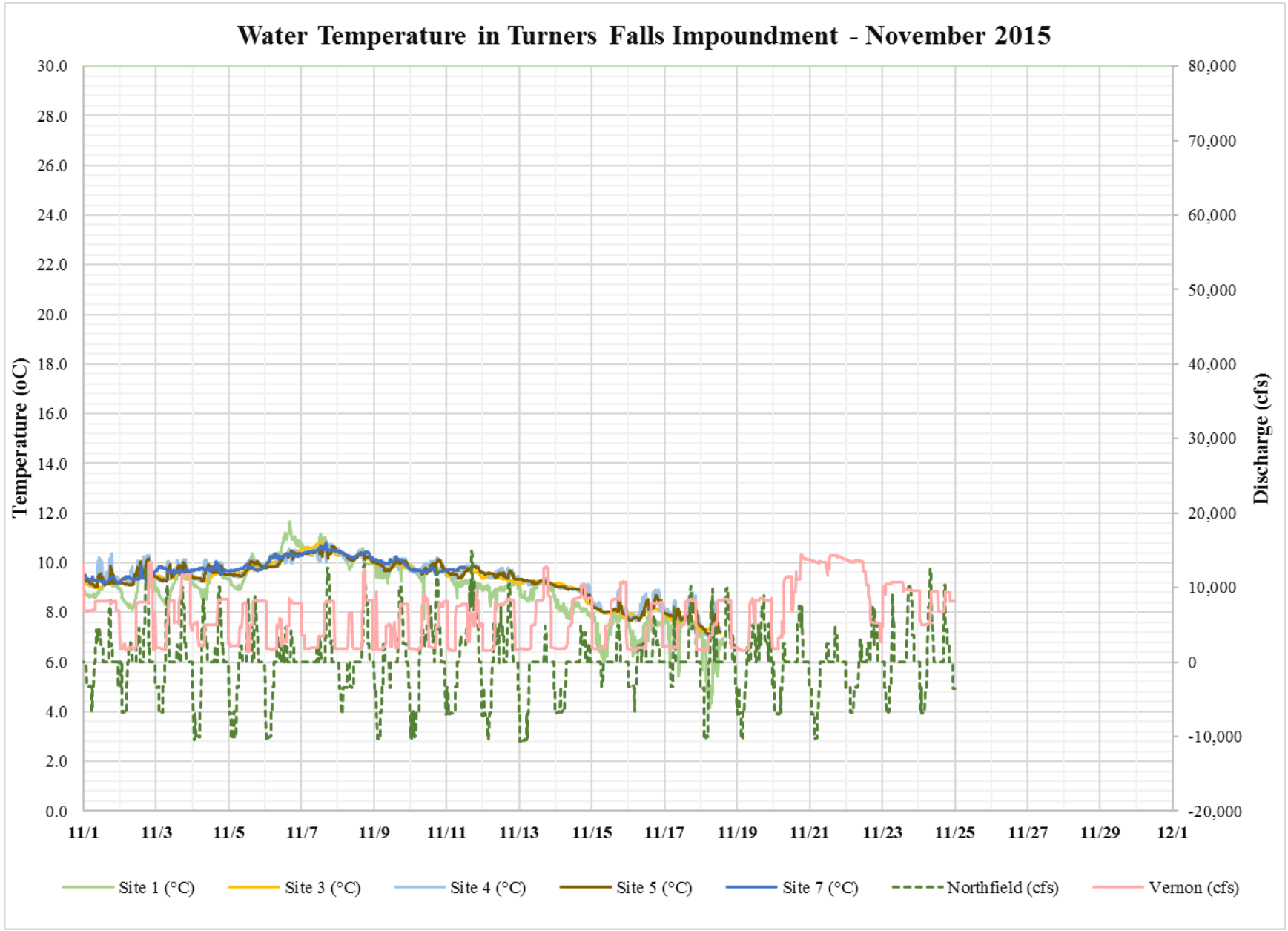

Water Temperature in Turners Falls Impoundment - June 2015
Temperature (oC)
Discharge (cfs)
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
6/1
6/3
6/5
6/7
6/9
6/11
6/13
6/15
6/17
6/19
6/21
6/23
6/25
6/27
6/29
7/1
Site 1 (°C)
Site 3 (°C)
Site 4 (°C)
Site 5 (°C)
Site 7 (°C)
Northfield (cfs)
Vernon (cfs)

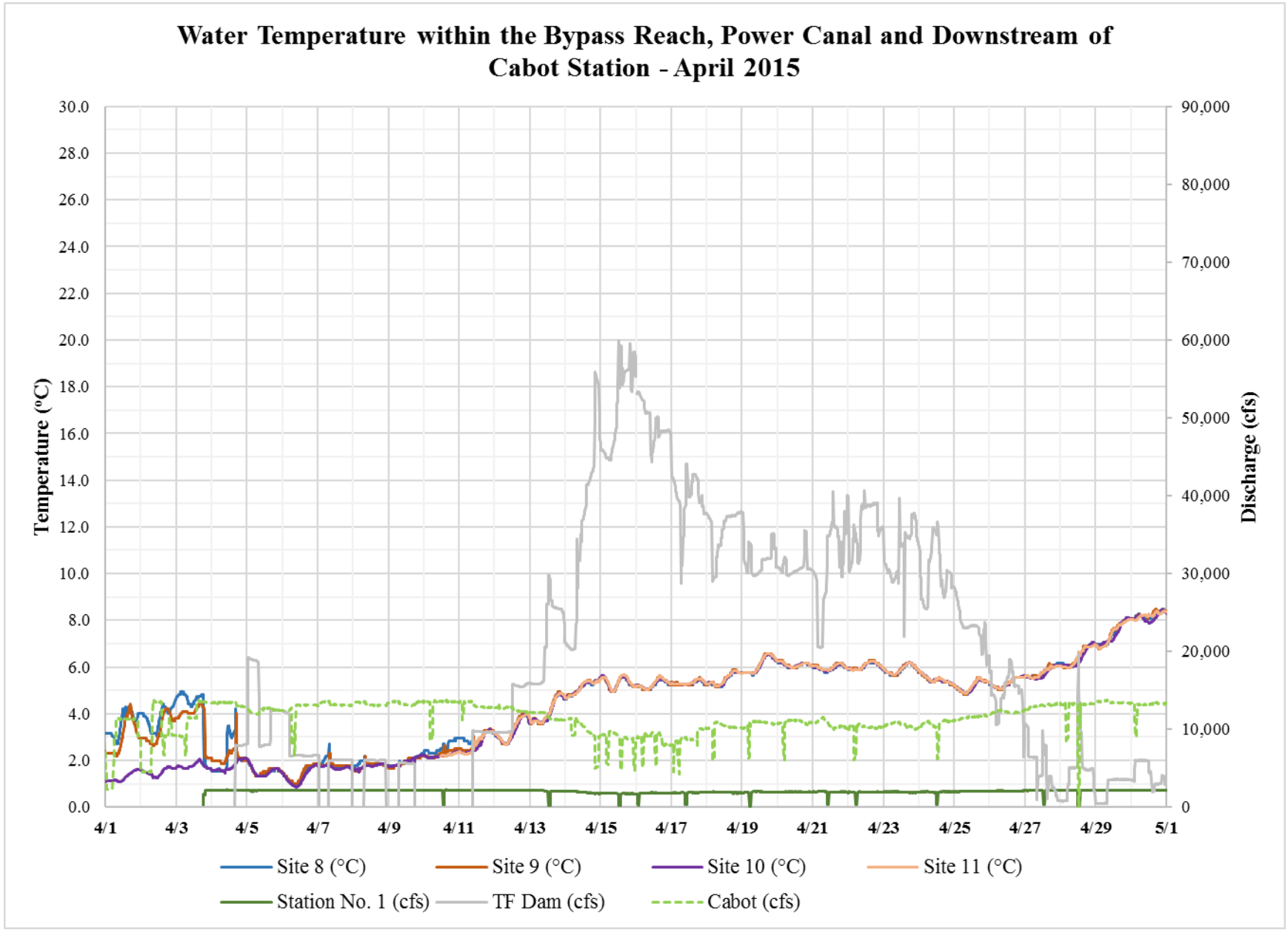

Water Temperature in Turners Falls Impoundment - July 2015
Temperature (oC)
Discharge (cfs)
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
7/1
7/3
7/5
7/7
7/9
7/11
7/13
7/15
7/17
7/19
7/21
7/23
7/25
7/27
7/29
7/31
Site 1 (°C)
Site 3 (°C)
Site 4 (°C)
Site 5 (°C)
Site 7 (°C)
Northfield (cfs)
Vernon (cfs)

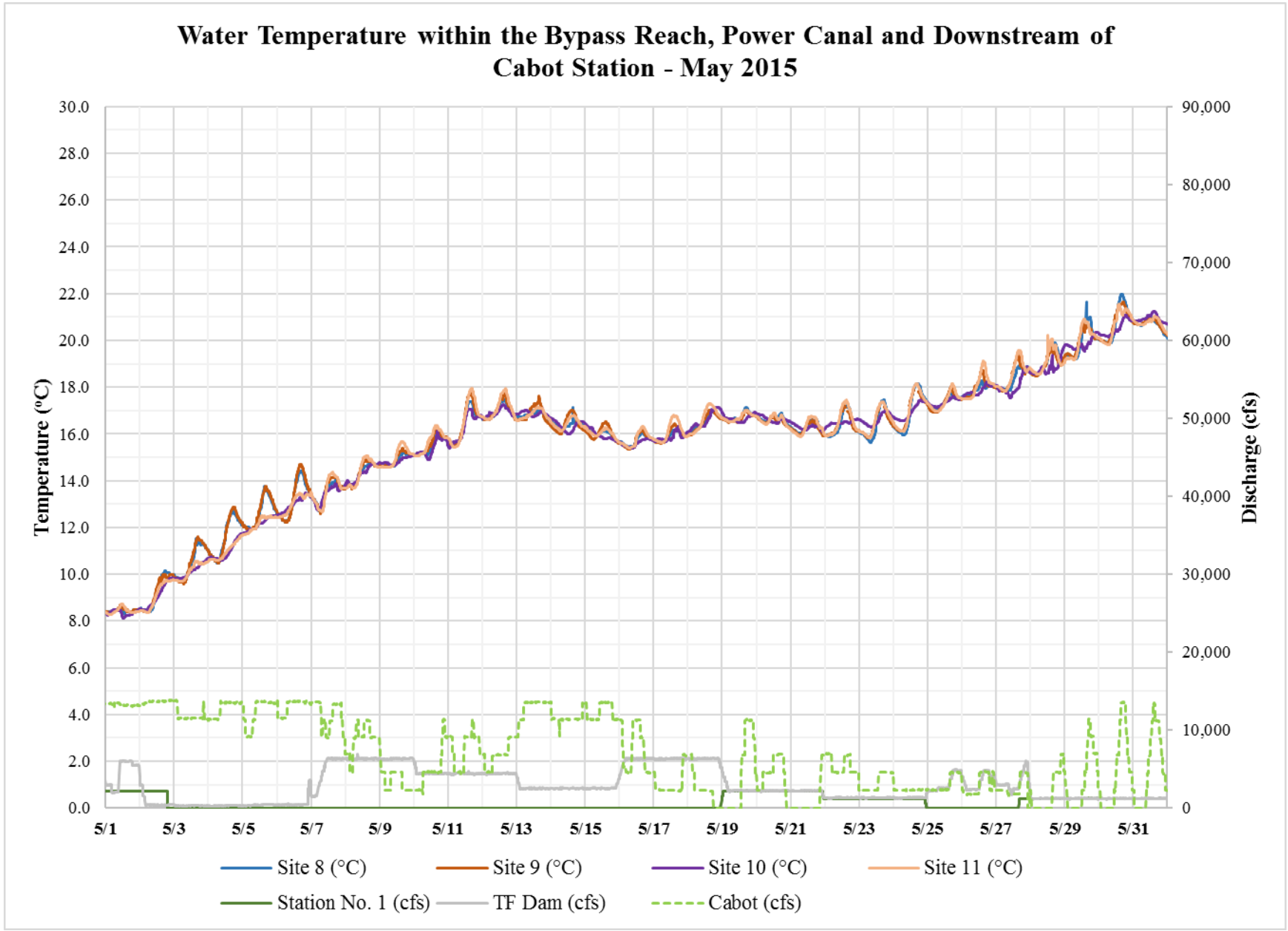

Water Temperature in Turners Falls Impoundment - August 2015
Temperature (oC)
Discharge (cfs)
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
8/1
8/3
8/5
8/7
8/9
8/11
8/13
8/15
8/17
8/19
8/21
8/23
8/25
8/27
8/29
8/31
Site 1 (°C)
Site 3 (°C)
Site 4 (°C)
Site 5 (°C)
Site 7 (°C)
Northfield (cfs)
Vernon (cfs)

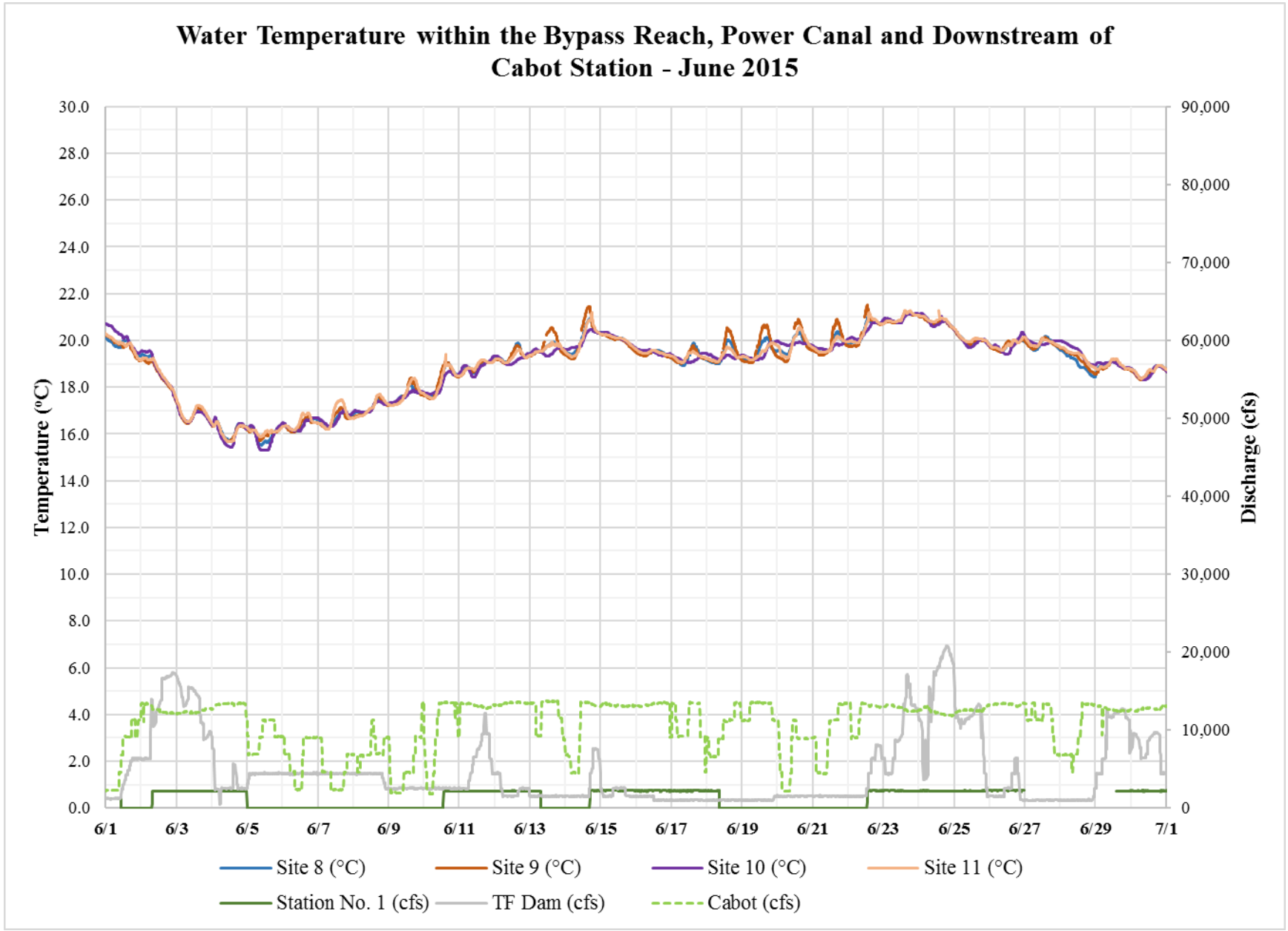

Water Temperature in Turners Falls Impoundment - September 2015
Temperature (oC)
Discharge (cfs)
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
9/1
9/3
9/5
9/7
9/9
9/11
9/13
9/15
9/17
9/19
9/21
9/23
9/25
9/27
9/29
10/1
Site 1 (°C)
Site 3 (°C)
Site 4 (°C)
Site 5 (°C)
Site 7 (°C)
Northfield (cfs)
Vernon (cfs)

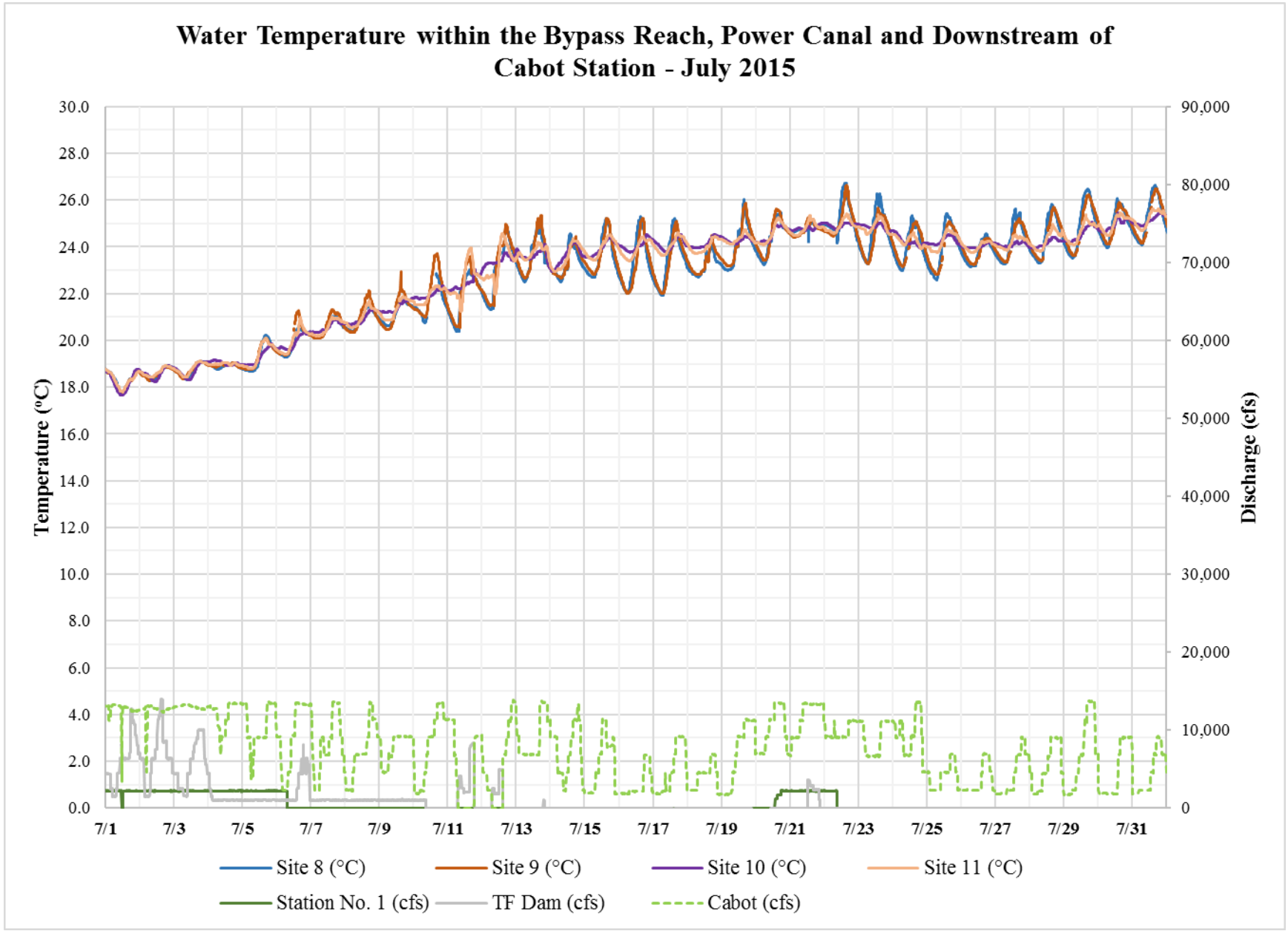

Water Temperature in Turners Falls Impoundment - October 2015
Temperature (oC)
Discharge (cfs)
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
10/1
10/3
10/5
10/7
10/9
10/11
10/13
10/15
10/17
10/19
10/21
10/23
10/25
10/27
10/29
10/31
Site 1 (°C)
Site 3 (°C)
Site 4 (°C)
Site 5 (°C)
Site 7 (°C)
Northfield (cfs)
Vernon (cfs)

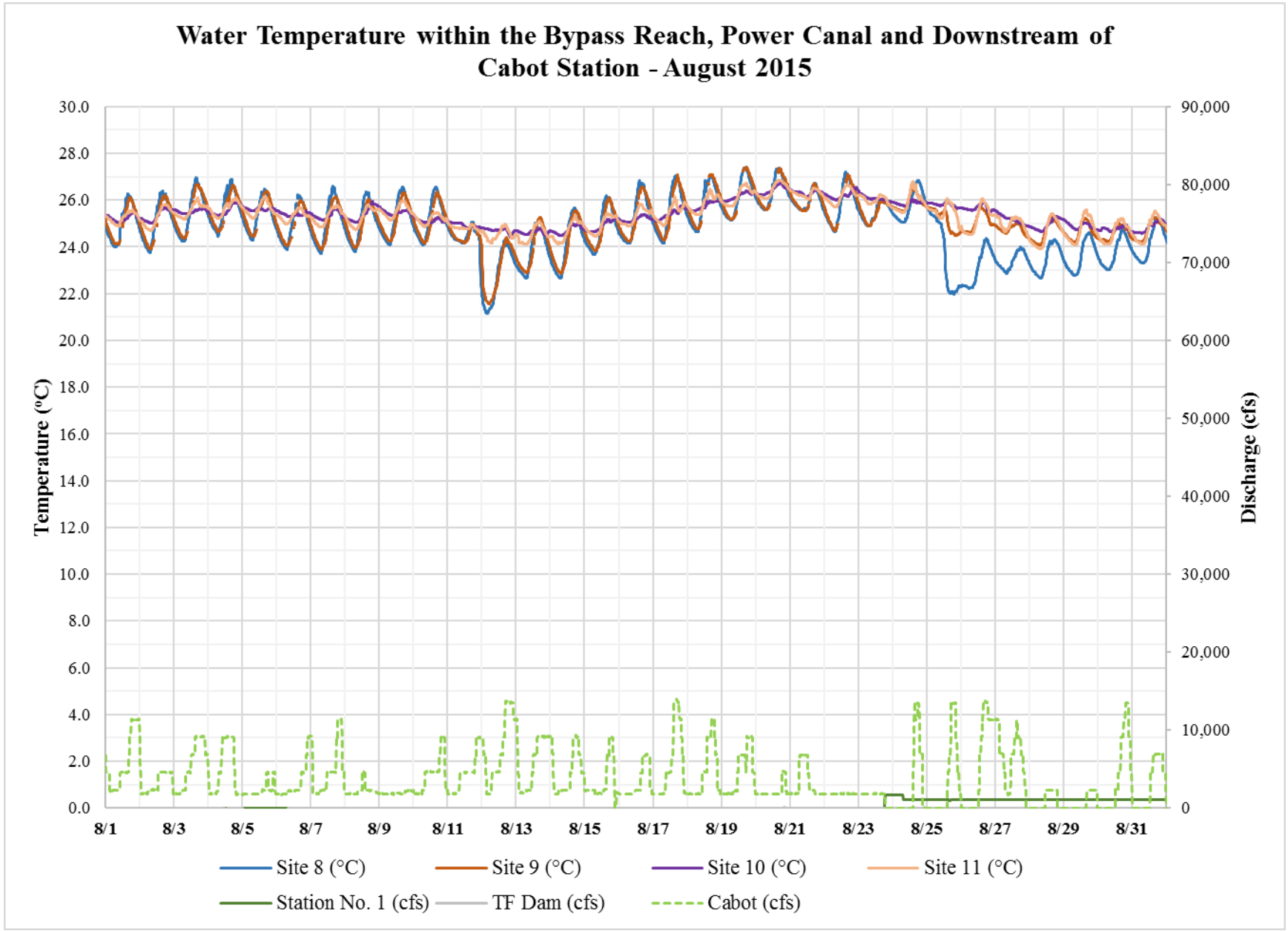

Water Temperature in Turners Falls Impoundment - November 2015
Temperature (oC)
Discharge (cfs)
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
11/1
11/3
11/5
11/7
11/9
11/11
11/13
11/15
11/17
11/19
11/21
11/23
11/25
11/27
11/29
12/1
Site 1 (°C)
Site 3 (°C)
Site 4 (°C)
Site 5 (°C)
Site 7 (°C)
Northfield (cfs)
Vernon (cfs)

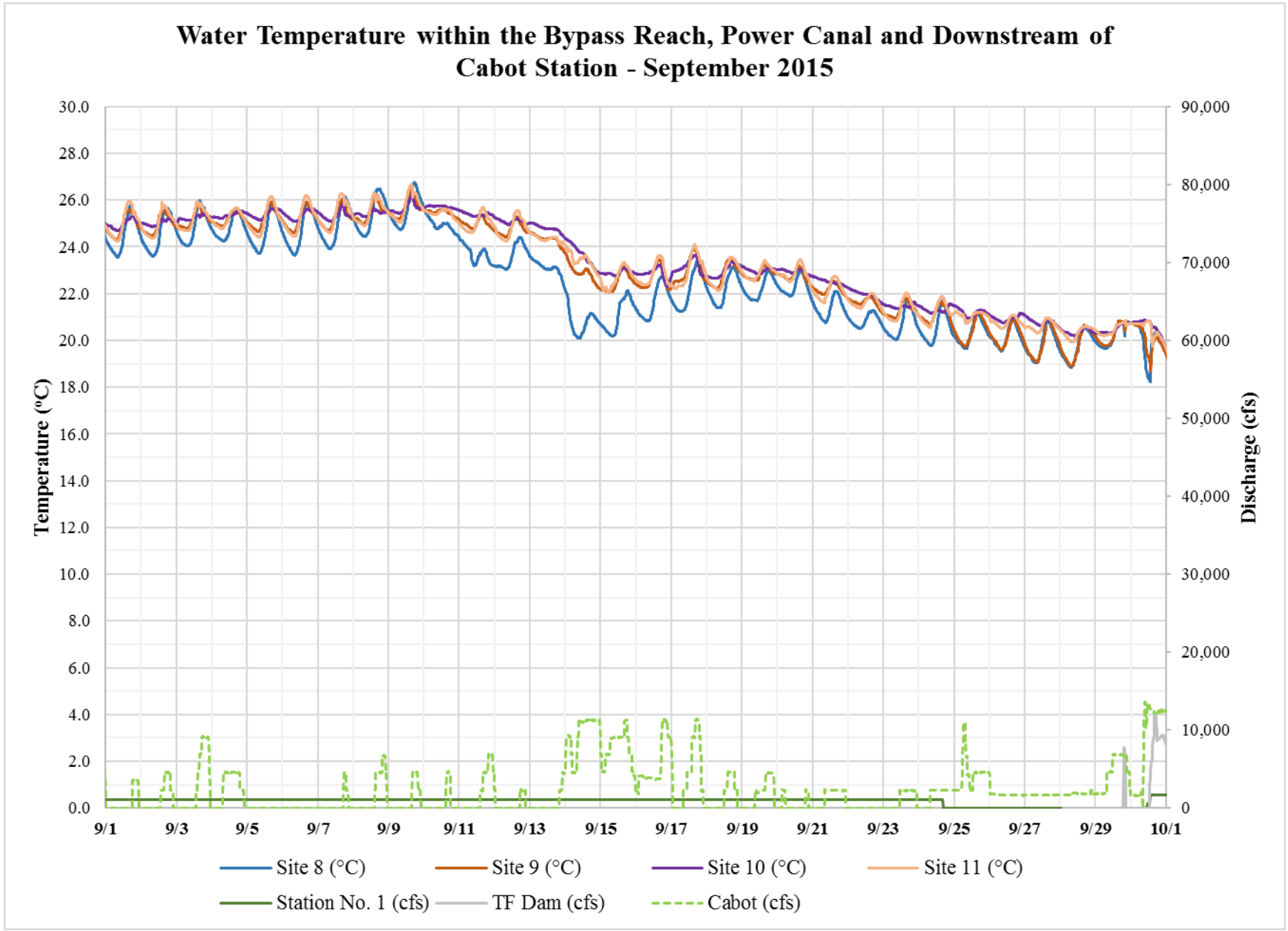

Water Temperature within the Bypass Reach, Power Canal and Downstream of Cabot Station - April 2015
Temperature (°C)
Discharge (cfs)
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
4/1
4/3
4/5
4/7
4/9
4/11
4/13
4/15
4/17
4/19
4/21
4/23
4/25
4/27
4/29
5/1
Site 8 (°C)
Site 9 (°C)
Site 10 (°C)
Site 11 (°C)
Station No. 1 (cfs)
TF Dam (cfs)
Cabot (cfs)

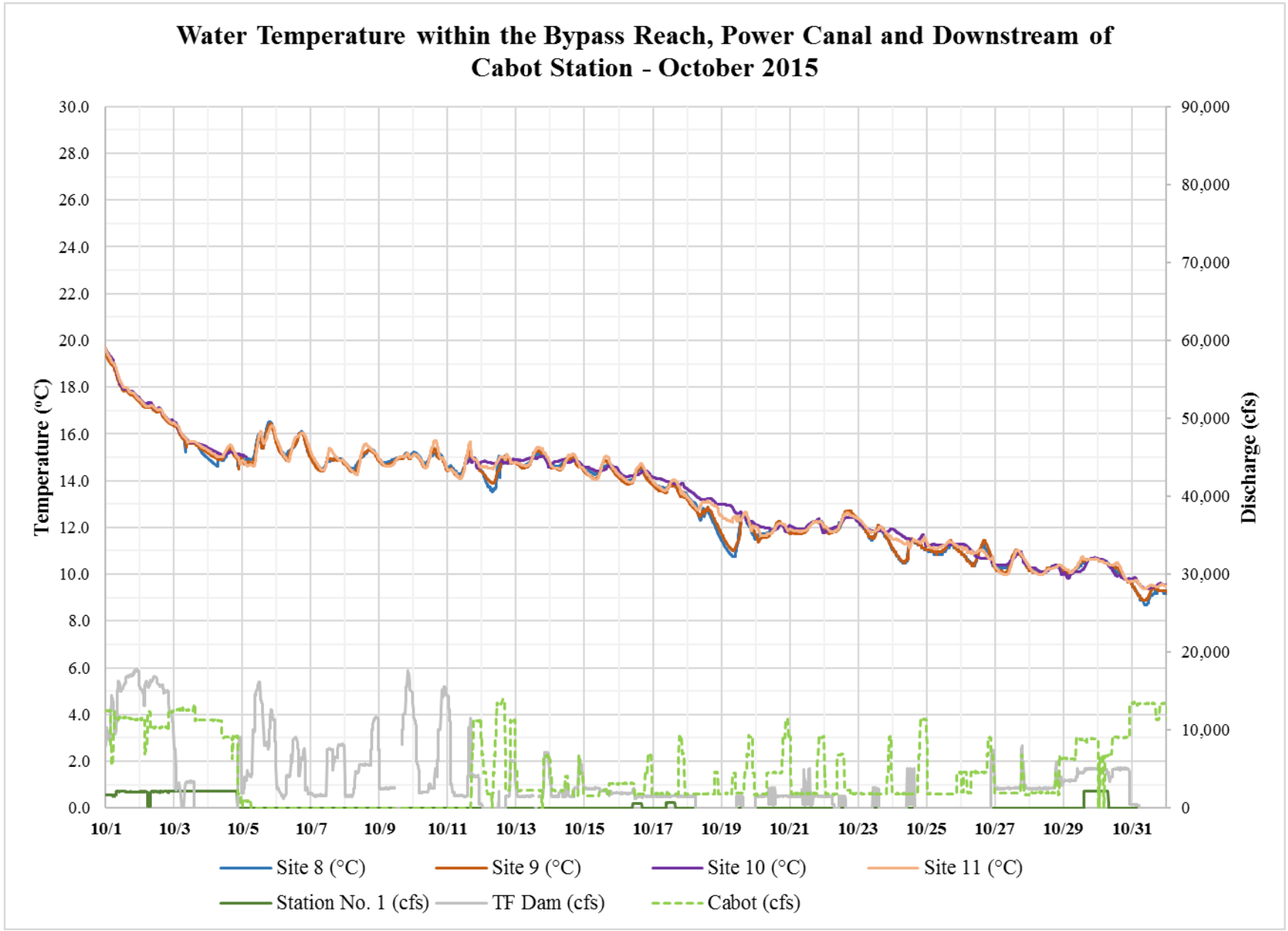

Water Temperature within the Bypass Reach, Power Canal and Downstream of Cabot Station - May 2015
Temperature (°C)
Discharge (cfs)
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
5/1
5/3
5/5
5/7
5/9
5/11
5/13
5/15
5/17
5/19
5/21
5/23
5/25
5/27
5/29
5/31
Site 8 (°C)
Site 9 (°C)
Site 10 (°C)
Site 11 (°C)
Station No. 1 (cfs)
TF Dam (cfs)
Cabot (cfs)

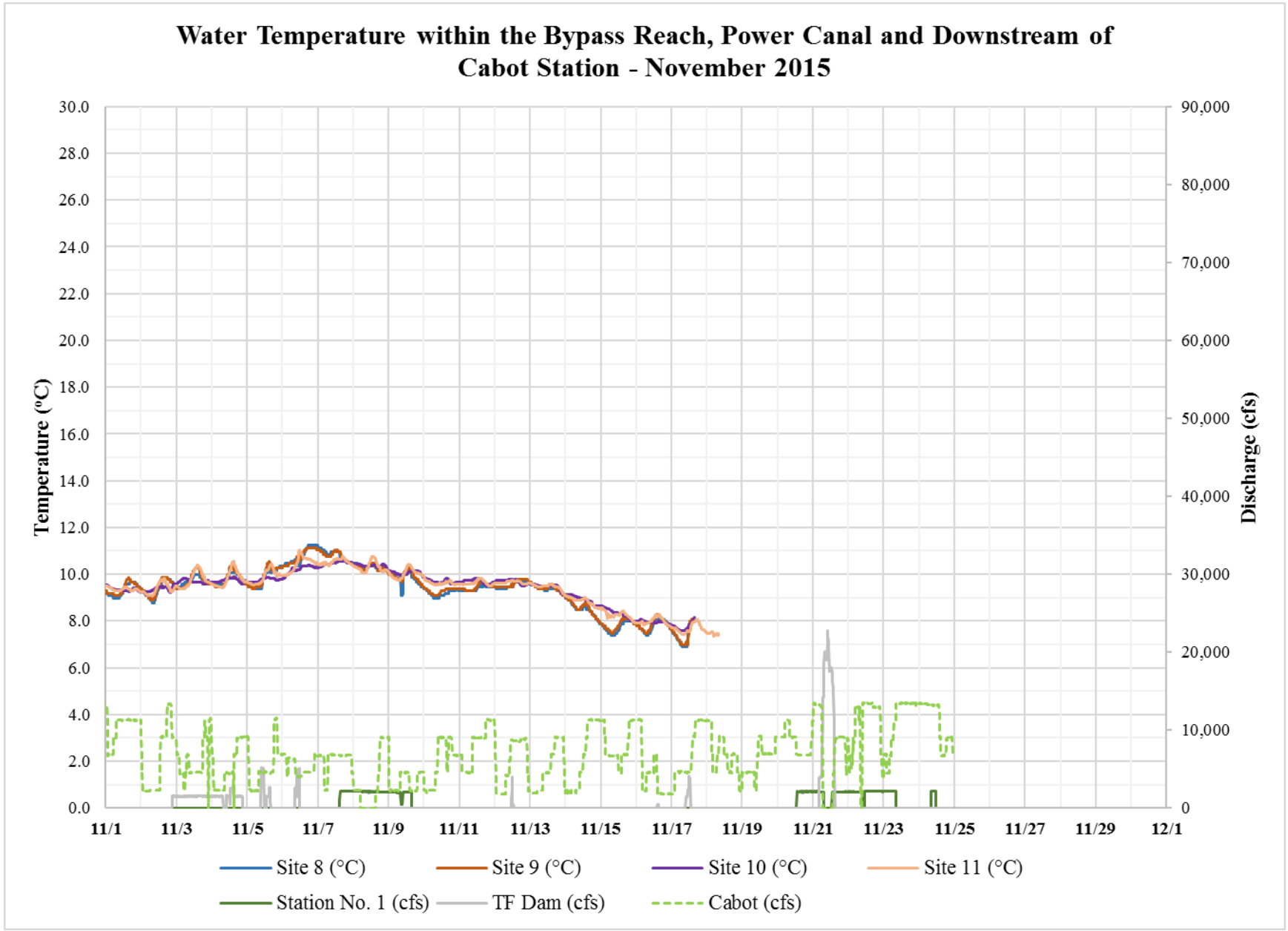

Water Temperature within the Bypass Reach, Power Canal and Downstream of Cabot Station - June 2015
Temperature (°C)
Discharge (cfs)
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
6/1
6/3
6/5
6/7
6/9
6/11
6/13
6/15
6/17
6/19
6/21
6/23
6/25
6/27
6/29
7/1
Site 8 (°C)
Site 9 (°C)
Site 10 (°C)
Site 11 (°C)
Station No. 1 (cfs)
TF Dam (cfs)
Cabot (cfs)

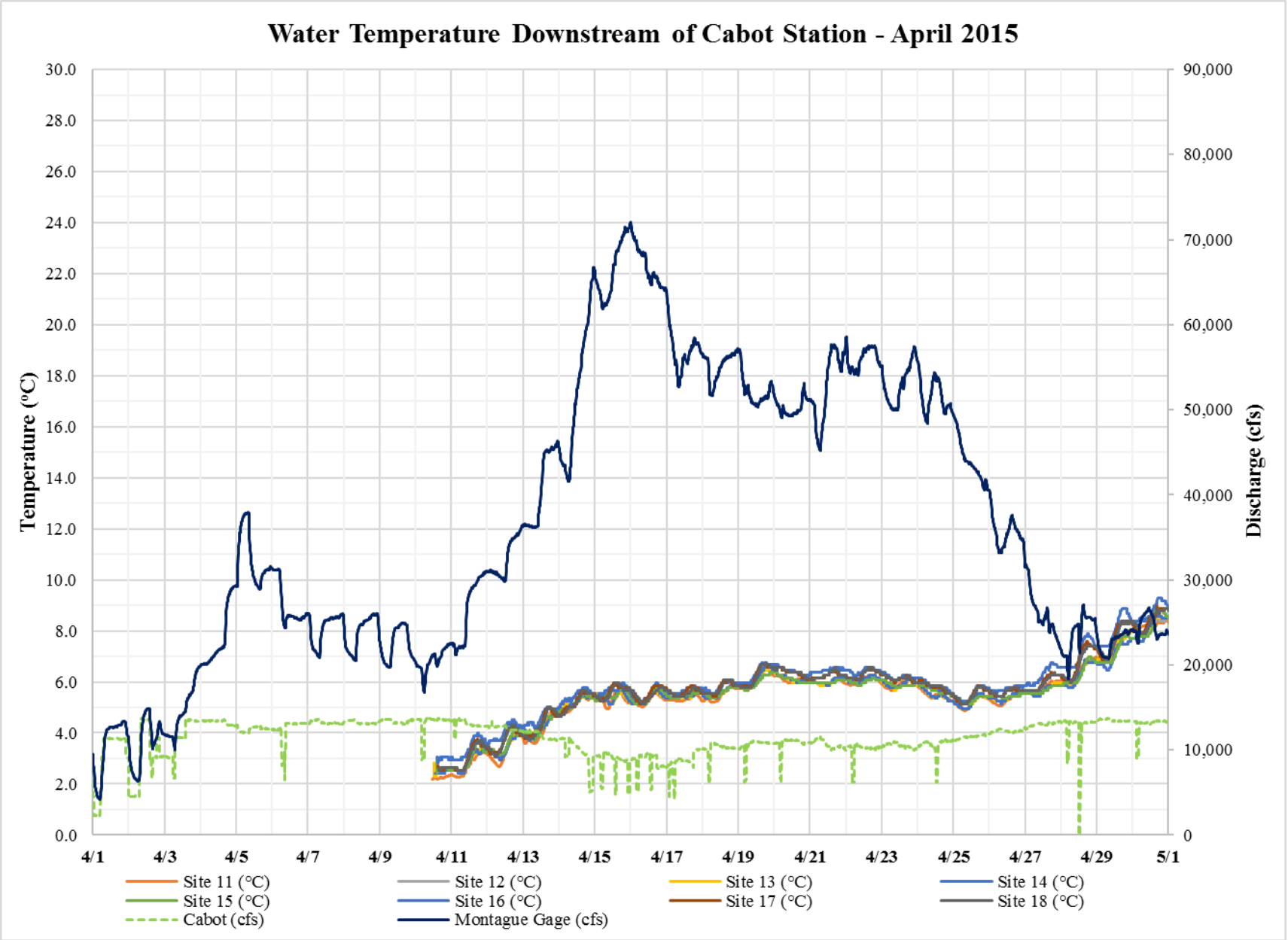

Water Temperature within the Bypass Reach, Power Canal and Downstream of Cabot Station - July 2015
Temperature (°C)
Discharge (cfs)
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
7/1
7/3
7/5
7/7
7/9
7/11
7/13
7/15
7/17
7/19
7/21
7/23
7/25
7/27
7/29
7/31
Site 8 (°C)
Site 9 (°C)
Site 10 (°C)
Site 11 (°C)
Station No. 1 (cfs)
TF Dam (cfs)
Cabot (cfs)

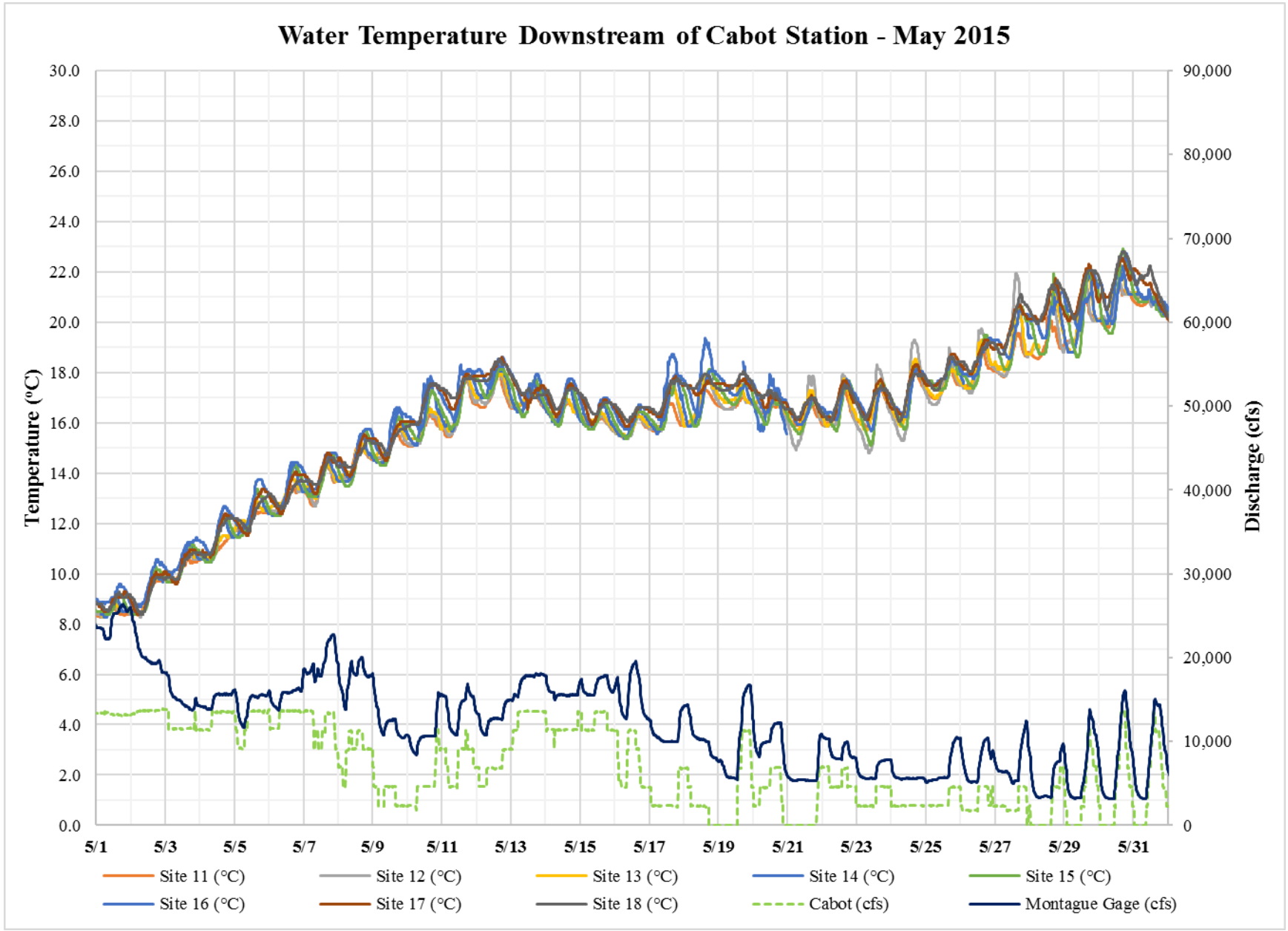

Water Temperature within the Bypass Reach, Power Canal and Downstream of Cabot Station - August 2015
Temperature (°C)
Discharge (cfs)
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
8/1
8/3
8/5
8/7
8/9
8/11
8/13
8/15
8/17
8/19
8/21
8/23
8/25
8/27
8/29
8/31
Site 8 (°C)
Site 9 (°C)
Site 10 (°C)
Site 11 (°C)
Station No. 1 (cfs)
TF Dam (cfs)
Cabot (cfs)

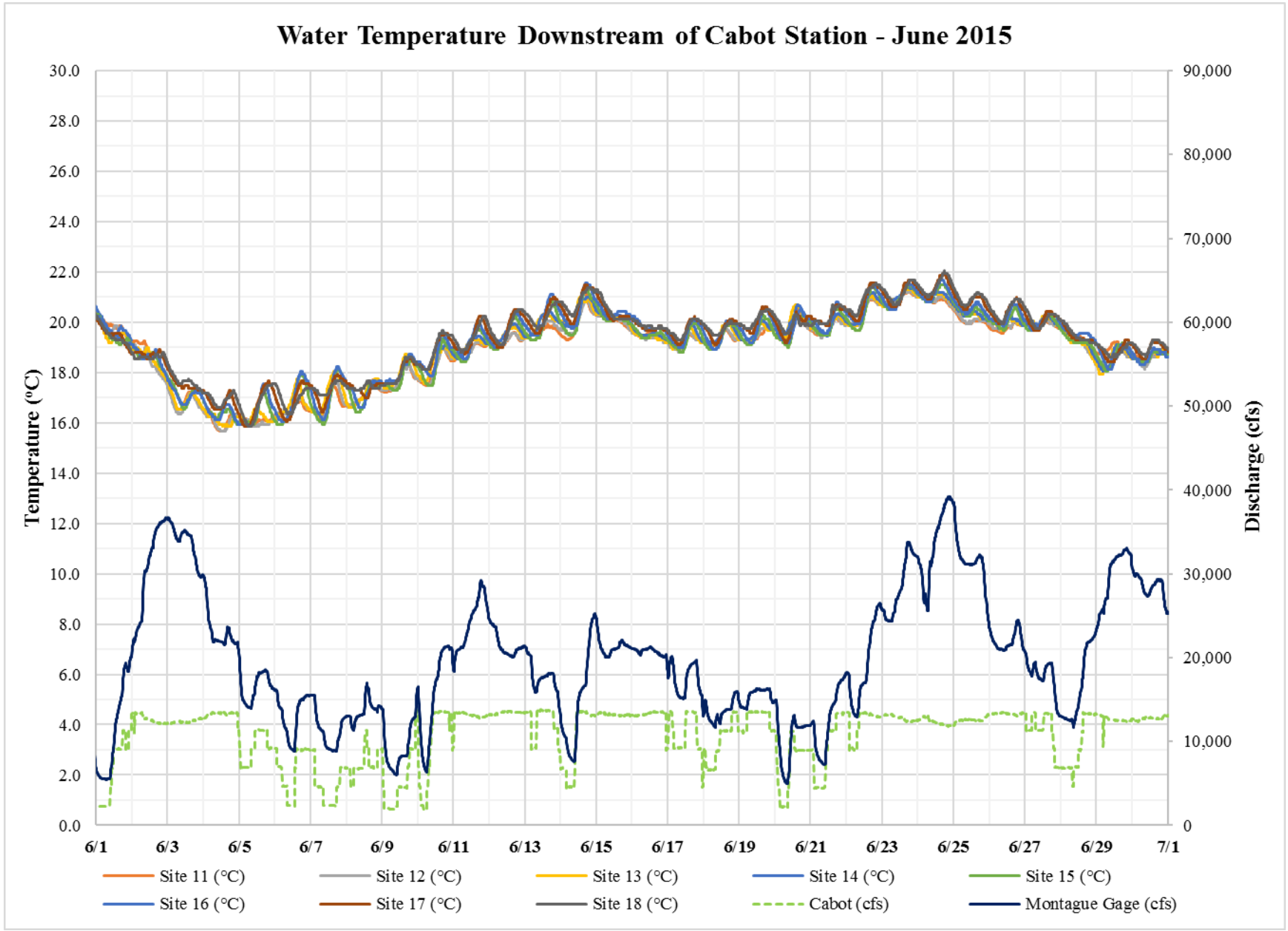

Water Temperature within the Bypass Reach, Power Canal and Downstream of Cabot Station - September 2015
Temperature (°C)
Discharge (cfs)
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
9/1
9/3
9/5
9/7
9/9
9/11
9/13
9/15
9/17
9/19
9/21
9/23
9/25
9/27
9/29
10/1
Site 8 (°C)
Site 9 (°C)
Site 10 (°C)
Site 11 (°C)
Station No. 1 (cfs)
TF Dam (cfs)
Cabot (cfs)

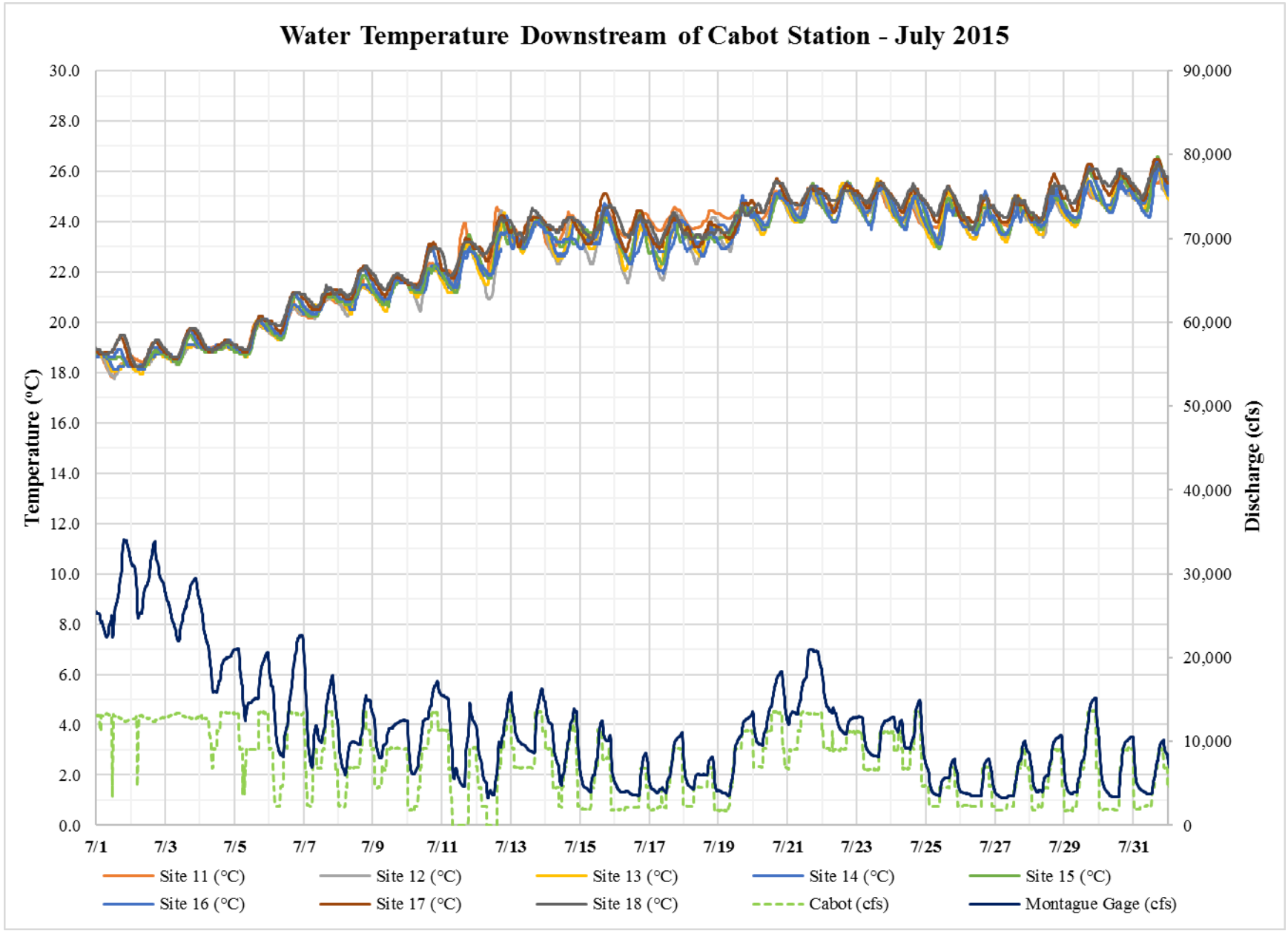

Water Temperature within the Bypass Reach, Power Canal and Downstream of Cabot Station - October 2015
Temperature (°C)
Discharge (cfs)
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
10/1
10/3
10/5
10/7
10/9
10/11
10/13
10/15
10/17
10/19
10/21
10/23
10/25
10/27
10/29
10/31
Site 8 (°C)
Site 9 (°C)
Site 10 (°C)
Site 11 (°C)
Station No. 1 (cfs)
TF Dam (cfs)
Cabot (cfs)

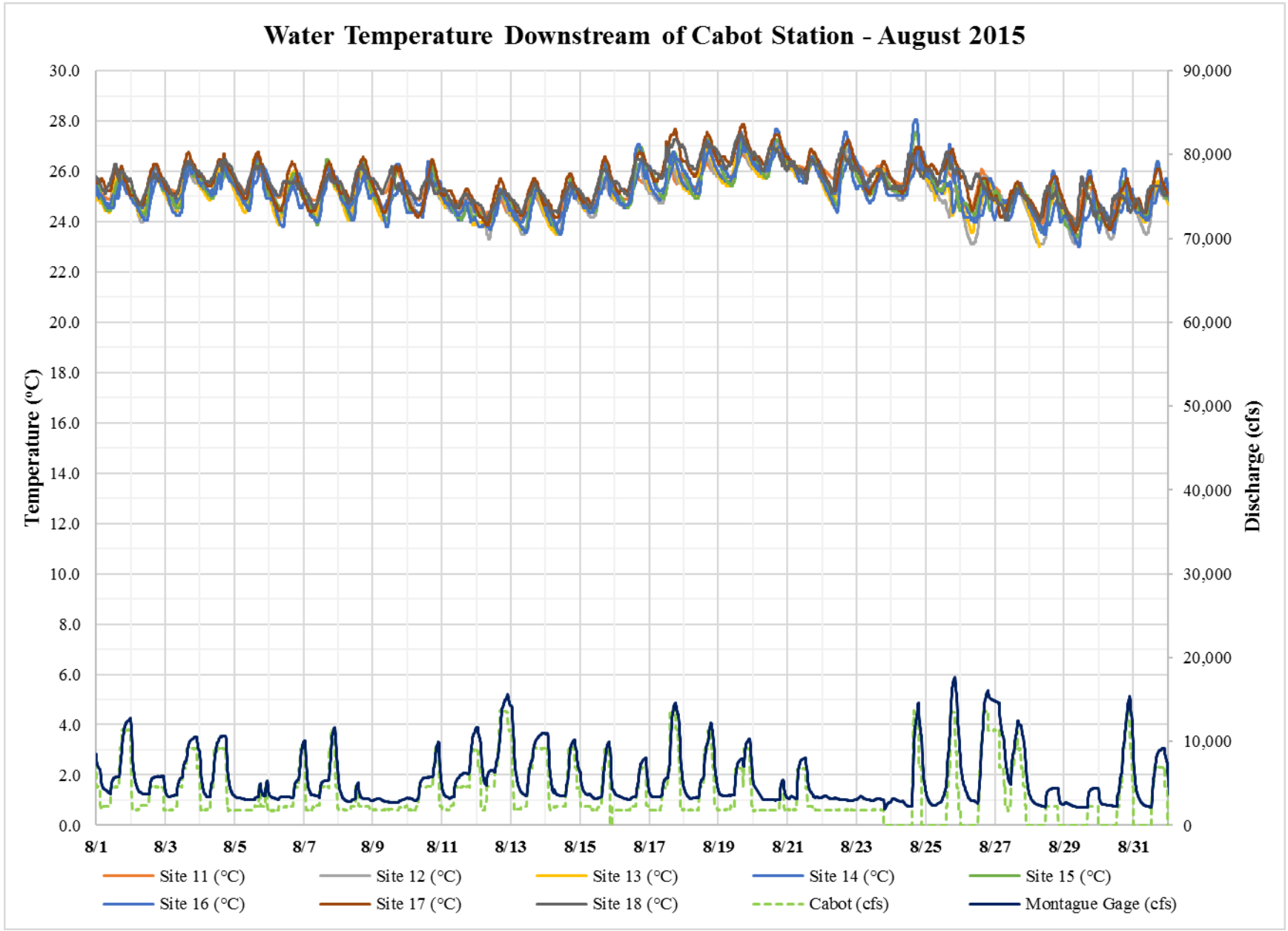

Water Temperature within the Bypass Reach, Power Canal and Downstream of Cabot Station - November 2015
Temperature (°C)
Discharge (cfs)
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
11/1
11/3
11/5
11/7
11/9
11/11
11/13
11/15
11/17
11/19
11/21
11/23
11/25
11/27
11/29
12/1
Site 8 (°C)
Site 9 (°C)
Site 10 (°C)
Site 11 (°C)
Station No. 1 (cfs)
TF Dam (cfs)
Cabot (cfs)

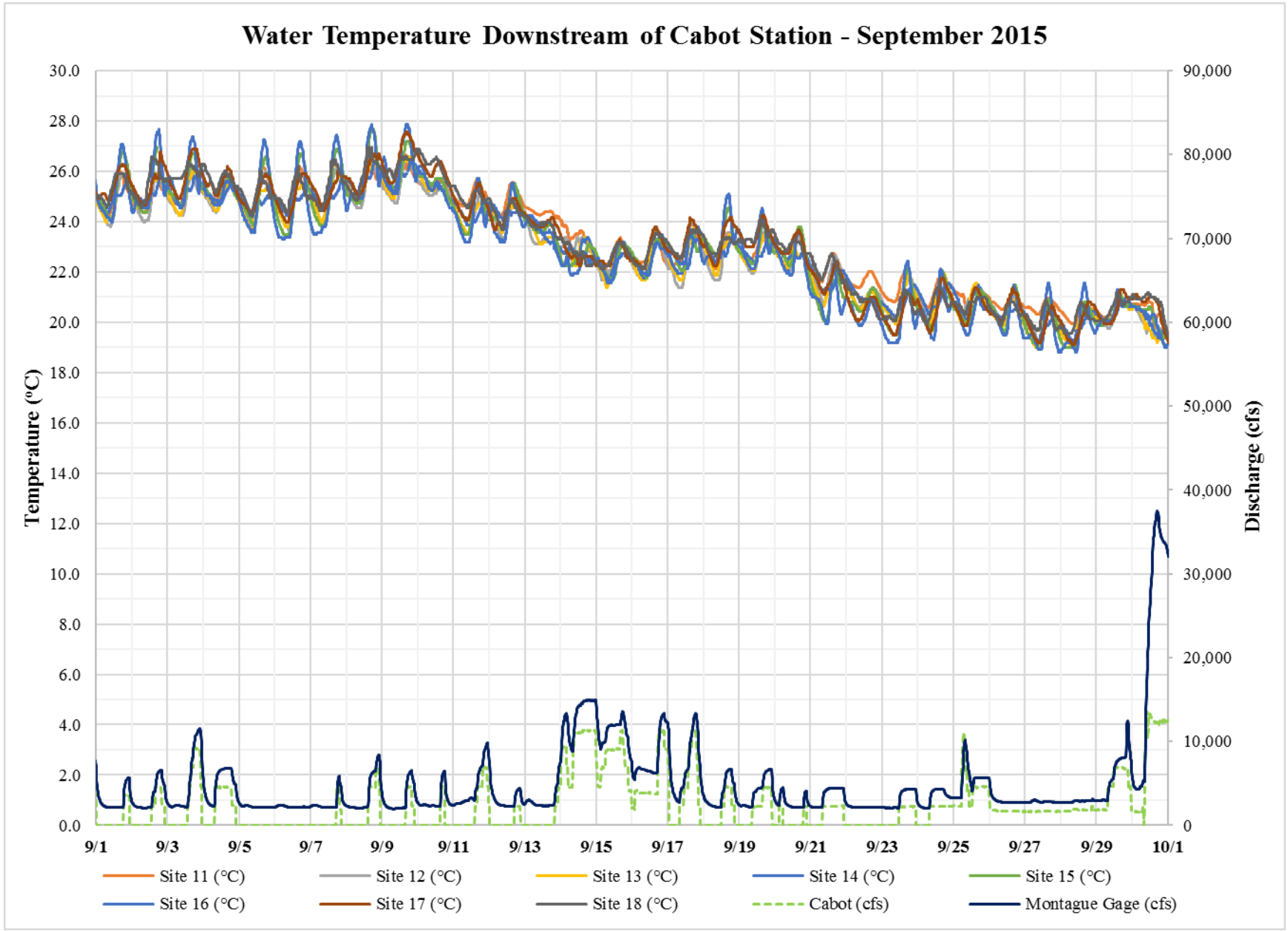

Water Temperature Downstream of Cabot Station - April 2015
Temperature (°C)
Discharge (cfs)
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
4/1
4/3
4/5
4/7
4/9
4/11
4/13
4/15
4/17
4/19
4/21
4/23
4/25
4/27
4/29
5/1
Site 11 (°C)
Site 12 (°C)
Site 13 (°C)
Site 14 (°C)
Site 15 (°C)
Site 16 (°C)
Site 17 (°C)
Site 18 (°C)
Cabot (cfs)
Montague Gage (cfs)

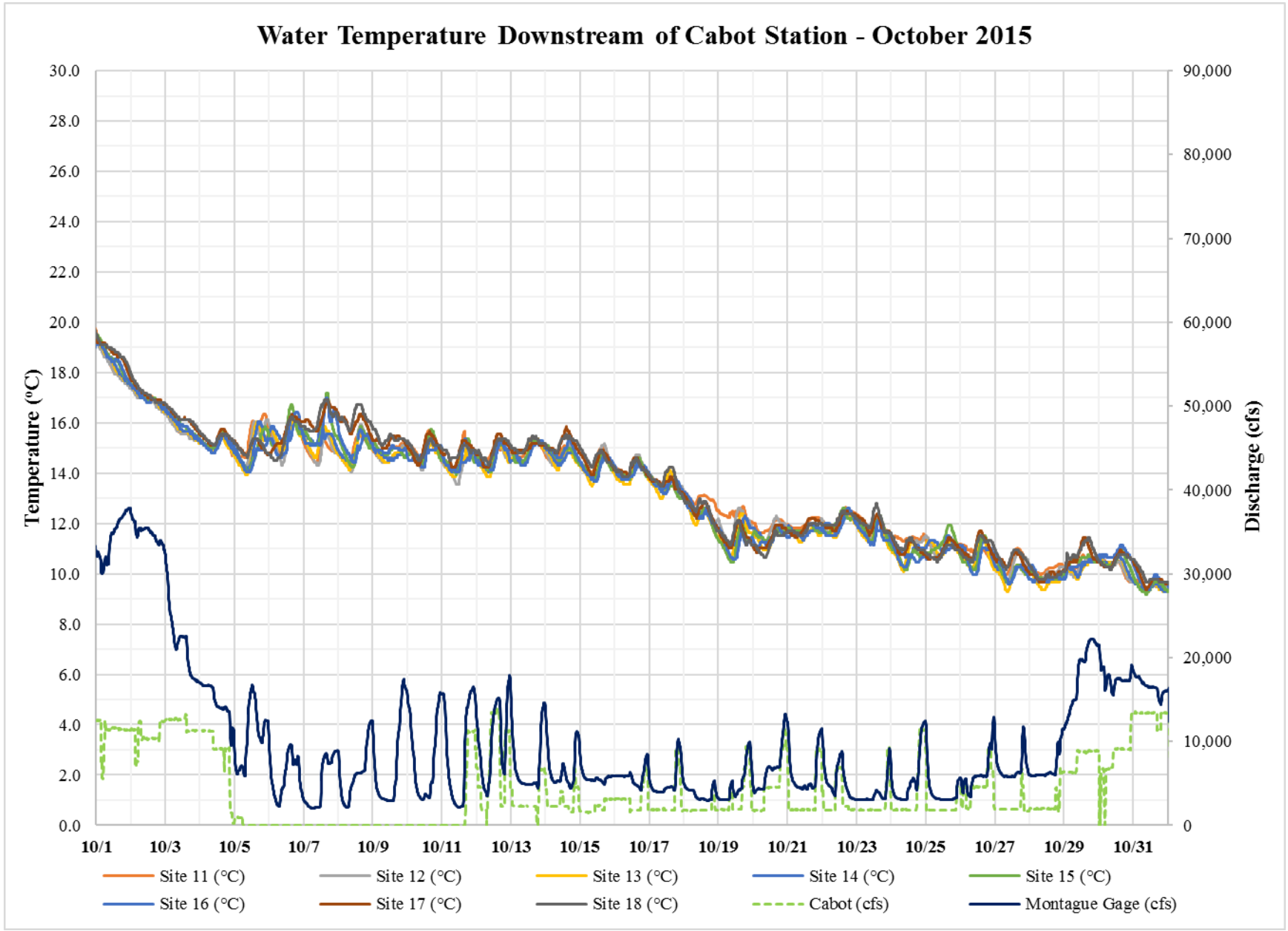

Water Temperature Downstream of Cabot Station - May 2015
Temperature (°C)
Discharge (cfs)
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
5/1
5/3
5/5
5/7
5/9
5/11
5/13
5/15
5/17
5/19
5/21
5/23
5/25
5/27
5/29
5/31
Site 11 (°C)
Site 12 (°C)
Site 13 (°C)
Site 14 (°C)
Site 15 (°C)
Site 16 (°C)
Site 17 (°C)
Site 18 (°C)
Cabot (cfs)
Montague Gage (cfs)

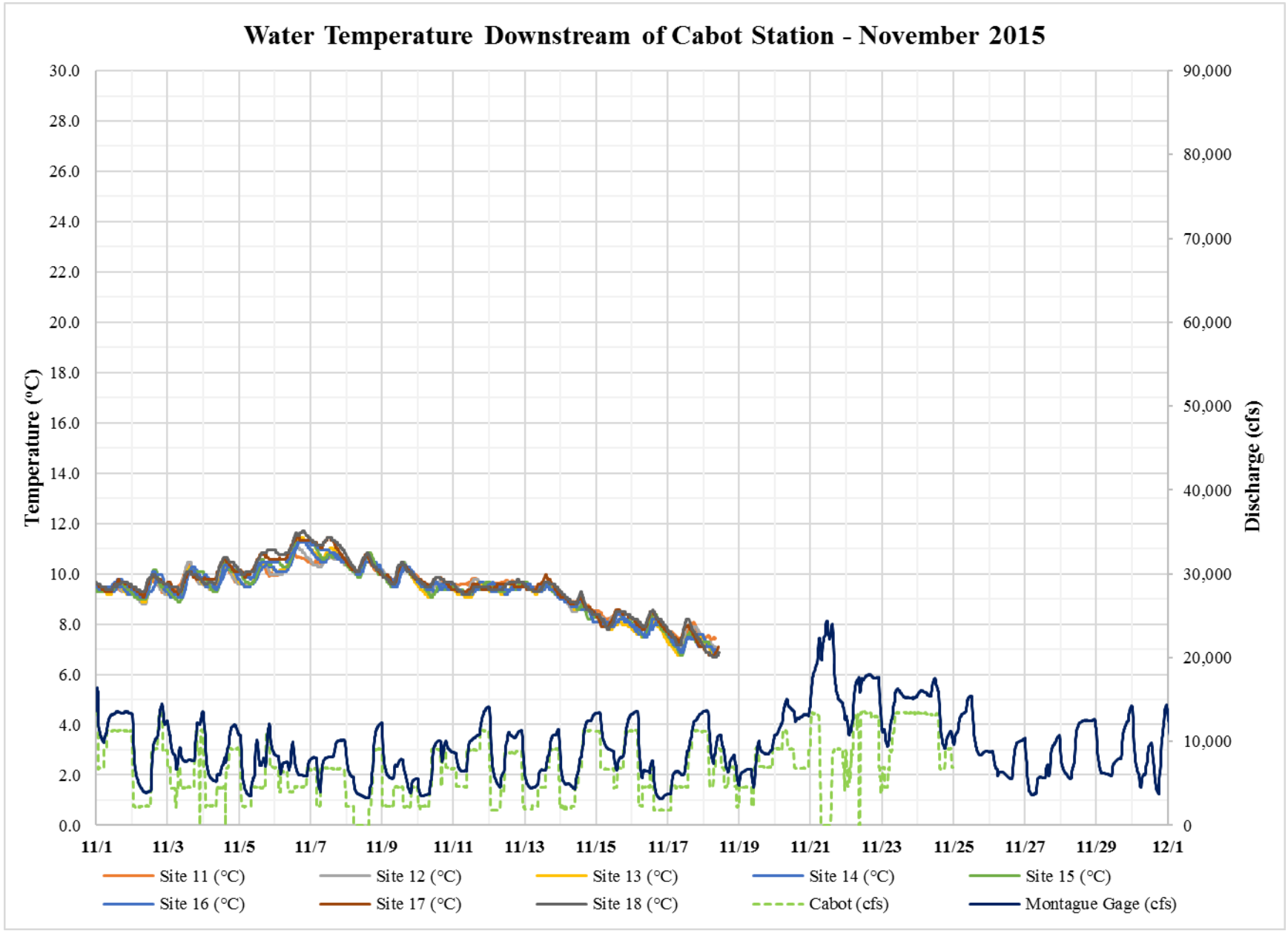

Water Temperature Downstream of Cabot Station - June 2015
Temperature (°C)
Discharge (cfs)
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
6/1
6/3
6/5
6/7
6/9
6/11
6/13
6/15
6/17
6/19
6/21
6/23
6/25
6/27
6/29
7/1
Site 11 (°C)
Site 12 (°C)
Site 13 (°C)
Site 14 (°C)
Site 15 (°C)
Site 16 (°C)
Site 17 (°C)
Site 18 (°C)
Cabot (cfs)
Montague Gage (cfs)


Water Temperature Downstream of Cabot Station - July 2015
Temperature (°C)
Discharge (cfs)
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
7/1
7/3
7/5
7/7
7/9
7/11
7/13
7/15
7/17
7/19
7/21
7/23
7/25
7/27
7/29
7/31
Site 11 (°C)
Site 12 (°C)
Site 13 (°C)
Site 14 (°C)
Site 15 (°C)
Site 16 (°C)
Site 17 (°C)
Site 18 (°C)
Cabot (cfs)
Montague Gage (cfs)


Water Temperature Downstream of Cabot Station - August 2015
Temperature (°C)
Discharge (cfs)
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
8/1
8/3
8/5
8/7
8/9
8/11
8/13
8/15
8/17
8/19
8/21
8/23
8/25
8/27
8/29
8/31
Site 11 (°C)
Site 12 (°C)
Site 13 (°C)
Site 14 (°C)
Site 15 (°C)
Site 16 (°C)
Site 17 (°C)
Site 18 (°C)
Cabot (cfs)
Montague Gage (cfs)


Water Temperature Downstream of Cabot Station - September 2015
Temperature (°C)
Discharge (cfs)
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
9/1
9/3
9/5
9/7
9/9
9/11
9/13
9/15
9/17
9/19
9/21
9/23
9/25
9/27
9/29
10/1
Site 11 (°C)
Site 12 (°C)
Site 13 (°C)
Site 14 (°C)
Site 15 (°C)
Site 16 (°C)
Site 17 (°C)
Site 18 (°C)
Cabot (cfs)
Montague Gage (cfs)


Water Temperature Downstream of Cabot Station - October 2015
Temperature (°C)
Discharge (cfs)
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
10/1
10/3
10/5
10/7
10/9
10/11
10/13
10/15
10/17
10/19
10/21
10/23
10/25
10/27
10/29
10/31
Site 11 (°C)
Site 12 (°C)
Site 13 (°C)
Site 14 (°C)
Site 15 (°C)
Site 16 (°C)
Site 17 (°C)
Site 18 (°C)
Cabot (cfs)
Montague Gage (cfs)


Water Temperature Downstream of Cabot Station - November 2015
Temperature (°C)
Discharge (cfs)
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
11/1
11/3
11/5
11/7
11/9
11/11
11/13
11/15
11/17
11/19
11/21
11/23
11/25
11/27
11/29
12/1
Site 11 (°C)
Site 12 (°C)
Site 13 (°C)
Site 14 (°C)
Site 15 (°C)
Site 16 (°C)
Site 17 (°C)
Site 18 (°C)
Cabot (cfs)
Montague Gage (cfs)