Appendix B – Water Quality Study

River Falls Hydroelectric Project P-10489

Dissolved Oxygen and Temperature Monitoring

Updated Study Report on 2019 and 2020 Monitoring Seasons

Prepared for:

River Falls Municipal Utilities
River Falls, WI

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River Falls Hydroelectric Project, P-10489

Dissolved Oxygen and Temperature Monitoring

Updated Study Report on
2019 and 2020 Monitoring Seasons

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Background

River Falls (WI) Municipal Utilities is preparing an application for a new hydropower license for the River Falls Hydroelectric Project. The Project consists of two developments, from upstream to downstream Junction Falls and Powell Falls. Junction Falls Dam and Powell Falls Dam impound Lake George and Lake Louise respectively on the Kinnickinnic River. The entire Project is within the city limits of River Falls.

In response to resource agency requests the applicant conducted a two-year program to monitor summer dissolved oxygen and water temperatures in the Kinnickinic River in the project vicinity. An interim report presenting data collected at four locations in the summer of 2019 was prepared in January, 2020. After stakeholder consultation, an updated study plan was prepared for the summer of 2020. The present report covers both the 2019 and 2020 monitoring seasons. The 2019 season began in mid-July and ended in mid-September. In 2020, water quality monitors were deployed from May 15 to September 30, except for an interval in early July after a large flood event destroyed or displaced all of the monitoring instrumentation.

Study Procedure

Instrumentation installation, maintenance, and data downloads were conducted by personnel of Ayres Associates as described below.

Equipment

Four HOBO U26-001 continuous DO and temperature sensors with dataloggers were installed with auxiliary components including a data shuttle, base station, anti-fouling guard, sensor cap, and data management software. The product specifications for DO list an accuracy of 0.2 mg/L and monitoring range of zero to 30 mg/L. Temperature accuracy of the sensors was listed as 0.2 degrees Celsius and an operating range of -5 to 40 degrees C (23 – 104 degrees Fahrenheit). The Hobo sensors were calibrated prior to deployment using a 3-step lab calibration method described in the product documentation. The product documentation states that lab calibration is valid for 6 months after calibration. However, because all of the sensors and dataloggers were replaced in July the longest deployment period after lab calibration was approximately 11 weeks. Gain and offset adjustment values were determined from the elevations of the installation sites.

Independent “grab sample” readings were taken at the time of the Hobo datalogger downloads and recorded in the field. The purpose of the grab samples was to confirm the performance of the continuous sensors, develop drift corrections if necessary, and describe spatial variations in water quality, especially in Lake George. The instrument used in 2019 was a YSI Model 55 handheld oxygen and temperature meter. In 2020, a YSI Pro 20 instrument was used. Product specifications for the YSI Model 55 used in 2019 list a DO accuracy of 0.3 mg/L and a monitoring range of 0 to 20 mg/L. Temperature accuracy is listed as 0.2º C (0.4º F) with a range of -5º to 45º C (23º to 113º F). Product specifications for the YSI Pro 20 used in 2020 list a DO accuracy of 0.2 mg/L for a monitoring range of 0 to 20 mg/L and an accuracy of plus or minus 6 percent for a monitoring range of 20 to 50 mg/L. Temperature accuracy is listed as 0.3º C (0.5ºF) with a range of -5º to 55º C (23º to 131º F). The YSI meter was calibrated before the site visits using the manufacturer’s recommended wet-sleeve “one touch” calibration method. In late July, some field readings suggested the YSI was not maintaining calibration and in August a second instrument (YSI

Pro ODO) was used to confirm the field readings. The duplicate readings indicated that the YSI Pro 20 was providing accurate readings and the late July inconsistencies did not reappear.

Monitoring Locations

The Hobo units (sensors and dataloggers) were placed at four locations as follows:

1. Project Inflow, upstream of Lake George in a free-flowing reach of river downstream from the Division Street bridge. This sensor recorded dissolved oxygen and temperature for flow entering the project area and prior to passage through the project impoundments, powerhouses or spillways. Flow in this location is shallow, fast-moving, and well mixed. The water depth at the sensor location was approximately 1.5 feet.

2. Lake George, the impoundment of Junction Falls Dam. The Hobo unit was installed approximately 600 feet upstream of Junction Falls Dam. According to the Lathrop-Lillie equation provided in the *Wisconsin 2020 Consolidated Assessment and Listing Methodology (WisCALM)* document (Wisconsin Department of Natural Resources, 2019, p.22), Lake George is considered a shallow, mixed (unstratified) water body. This calculation is based on a 16-acre surface area and 10-foot maximum depth as shown in the 2016 Inter-Fluve "Sediment Assessment Report" for Lake George. The depth at the sensor location was approximately three feet.

3. Junction Falls Outflow, downstream of Junction Falls Dam and powerhouse. The intent of this placement was to capture Lake George outflows while avoiding or minimizing effects from the South Fork of the Kinnickinnic, which enters on the opposite side of the river (southeast) from the powerhouse outfall. Grab samples were collected from both the South Fork outflow and the instrument location to provide a comparison between the streamflow sources. The instrument location was in a relatively deep (2.5 feet) and slow-moving pool below the dam.

4. Powell Falls Outflow, approximately 200 feet downstream from Powell Falls Dam. This is a free-flowing reach of river. Water depth at the sensor location was approximately 1.5 feet.

In 2019, the locations initially established were retained throughout the summer with the exception of the "Project Inflow" location, as discussed below. In 2020, public disturbance of the other installations was a much more persistent problem than in 2019, so some of the instruments were relocated or replaced in less visible and/or less accessible locations while preserving the general intent of the placements as described above. (The reason for the increase in apparent public interference is not known. Instruments were generally not stolen or destroyed, but on multiple occasions they were detached from their anchors, laid on the streambed, or left on the bank nearby).

Once installed, the Hobo unit locations were surveyed with a GPS. The Hobo locations are shown in Figures 1a (2019) and 1b (2020). In 2019, biweekly handheld meter measurements were made at the Hobo unit locations. Downloads and handheld meter readings were conducted somewhat more frequently (on average every ten days) in 2020 than in 2019. Each download visit included a check and cleaning of the Hobo sensor, sensor cap, and fouling guard.

In 2020, a YSI transect was also added across Lake George as indicated in Figure 1b. The 2020 study plan also called for longitudinal handheld meter measurements to be made downstream of Junction Falls and Powell Falls any time the measured dissolved oxygen at the continuous monitoring location below

the dam read below 6 mg/L. This condition did not occur on any of the download/sampling visits, although the continuous record suggests it occurred on some occasions between download visits.

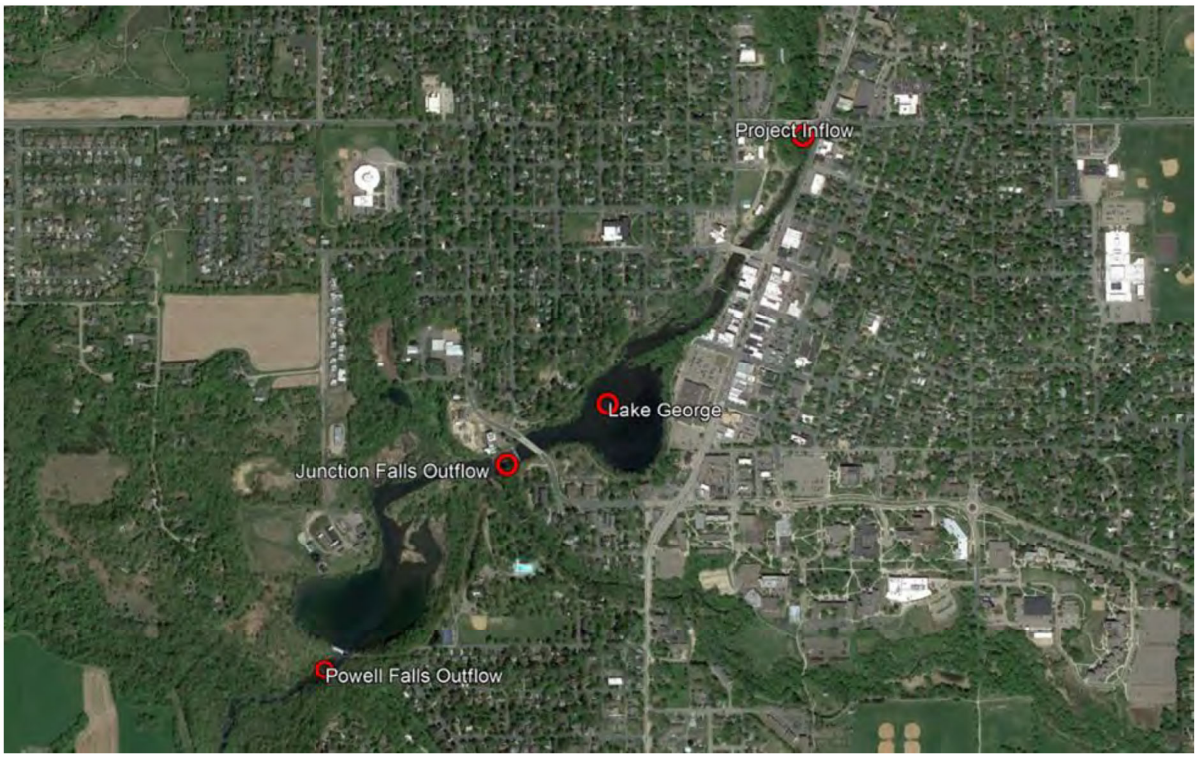


Figure 1a: Hobo Unit Locations (2019)

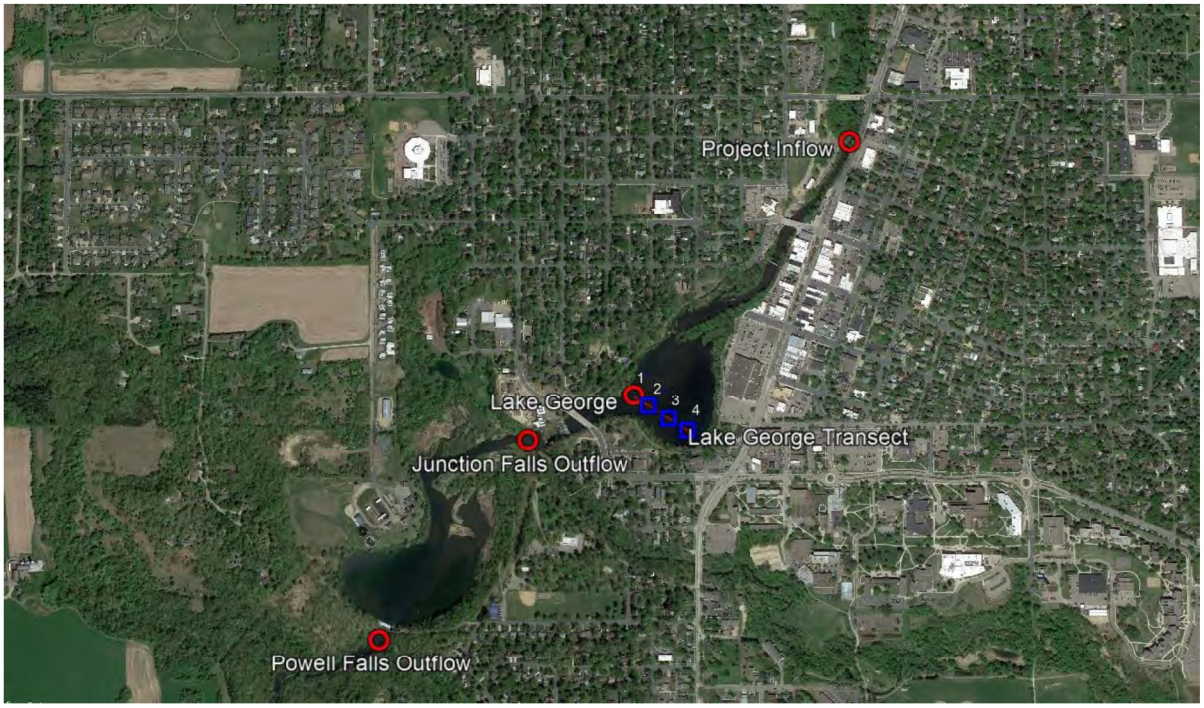


Figure 1b: Hobo Unit Locations (2020) (note new Lake George grab sample sites in blue)

Installation

Each sensor was attached to a slotted PVC pipe, anchored with one or more cinder blocks, and positioned approximately in the middle of the water column. Buoys were attached to the pipes to assist in retrieving the unit should it become detached from the anchor block. Figure 2 shows a typical installation.

Figure 2: Monitor installation downstream of Junction Falls Dam

The installations shown in Figure 2 were in place throughout the 2019 season. However, over the course of the summer of 2020, the PVC pipes at all but the Lake George location were eliminated as they seemed to attract public interference. The sensors were then attached to the cinder blocks themselves with no above-water visibility, positioned to maintain a mid-water-column vertical location.

Reading and Download Frequency

The Hobo dataloggers were programmed to record dissolved oxygen concentrations and water temperatures at 15-minute intervals, around the clock. Data were downloaded approximately every two weeks in 2019 and at one- to two-week intervals in 2020 as weather, flow conditions, and other instrument maintenance needs permitted. The Hobo sensors and fouling guards were cleaned at each visit and readings checked against the YSI meter data.

The “project inflow” monitoring location was problematic from a public disturbance perspective in both 2019 and 2020. In 2019, the anchor and buoy for the “project inflow” monitoring location unit were

vandalized almost immediately upon setup, prior to deployment of the data logger. The datalogger was then installed with additional contact and security information but was then removed or stolen sometime between July 23 and August 2. The unit was then replaced in a less conspicuous location, with the result that very limited “project inflow” readings are available before August 2, 2019. The unit was also moved in June 2020 to a less visible downstream location.

On the night of June 28-29, 2020, a rainstorm occurred that reportedly produced up to eight inches of rain in some parts of the Kinnikinnic watershed. The peak reported flow at the USGS gaging station downstream of River Falls was approximately 6,300 cfs. In comparison, the January 2021 *Hydraulic and Hydrologic Analysis, River Falls Hydroelectric Project* (U.S. Army Corps of Engineers, St. Paul District) presents an estimated 20-year flood magnitude of 6,550 cfs at the USGS gage, but also notes there is significant uncertainty in this estimate. The June 29, 2020 flow recorded at the USGS gaging station was 35 percent larger than the next largest event in the 24-year systematic record, but smaller than non-gaged floods reported from 1894, 1934, and 1965.

Figure 3 shows the June 29, 2020 flood at the Junction Falls spillway (photo provided by River Falls Municipal Utilities).

Figure 3. June 29, 2020 Flood at Junction Falls

All four Hobo installations were lost and could not be recovered following the June 29 flood event. Replacements were ordered immediately and were installed on July 17. Therefore, no continuous data are available between June 19 (the date of the last download visit) and July 17, 2020.

Table 1 lists the Hobo unit locations, water depths, and recording dates.

Table 1: Dissolved Oxygen/Temperature 15-Minute Recording Locations and Dates

Location	Water Depth (ft) at first placement (7-18-2019)	Recording Dates	Comments
Project Inflow	2.2	7/18 - 7/23, 2019 8/2 - 8/5, 2019 8/6 - 9/17, 2019 5/15 - 6/19, 2020 7/17 – 10/2, 2020	Free flowing reach, water depth varied throughout recording period. Sensor was placed in PVC pipe in 2019. In 2020 it was initially placed in PVC pipe but later attached to cinder block approximately 1 foot off the streambed due to repeated disturbance by the public.
Lake George	4.2	7/18 – 9/16, 2019 5/15 – 6/19, 2020 7/17 – 10/2, 2020	Impounded reach above Junction Falls Dam
Junction Falls Outflow	3.9	7/18 – 9/17, 2019 5/15 – 5/29, 2020 6/12 – 6/19, 2020 7/17 – 10/2, 2020	Placed in pool near western shoreline to capture powerhouse/spillway outflows with minimal impact by South Fork Found removed from stream and left on streambank 6-12-2020.
Powell Falls Outflow	2.9	7/18 – 9/17, 2019 5/15 – 6/19, 2020 7/17 – 10/2, 2020	Free flowing reach, water depth varied throughout recording period. Some public disturbance; unit typically moved but left in the water.

Additional Data Collection

Additional data were collected as follows:

- Algae cover in Lake George was noted during data download visits. Algae cover was recorded photographically and visually estimated as a percentage of the lake's surface area.

- Independent measurements of dissolved oxygen and temperature were taken at the data logger sites during data download visits. These samples were taken within the top 18 inches of the water column using a YSI handheld temperature/DO meter.

-In Lake George, a vertical profile was sampled by taking YSI readings at depths near the top, center, and bottom of the water column. This was done in 2020 only, at the Hobo unit location and at three additional locations across a northwest-to-southeast transect as shown on Figure 1b.

- Daily average air temperatures for River Falls were retrieved from the Accuweather website (2019) and NOAA's online climate data repository (2020).

- Daily flows at USGS stream gage 05342000, located approximately eight river miles downstream of Powell Falls, were downloaded and plotted along with the water quality and air temperature data. The drainage area at the USGS gage is 23 percent larger than that at Powell Falls and 48 percent larger than that at Junction Falls. Therefore, the USGS gage flows should be seen as an index to the streamflow at the study location, not the actual local flow rate.

During the download visits at the Junction Falls and Powell Falls outflow monitors, field personnel were prepared to take additional downstream YSI readings if the dissolved oxygen concentrations in the dam's tailrace were found to be less than 6 mg/L. This condition did not occur during any of the site visits.

Applicable Water Quality Standards

The Kinnickinnic River is designated a Class I trout stream by the state of Wisconsin. Wisconsin's Administrative Code NR 102.04 states: *Dissolved oxygen in classified trout streams shall not be artificially lowered to less than 6.0 mg/L at any time, nor shall the dissolved oxygen be lowered to less than 7.0 mg/L during spawning season.*

For waters that are not designated trout streams, NR 102.04 specifies a minimum dissolved oxygen concentration of 5.0 mg/L.

Chapter NR 102.25 also presents monthly temperature standards for cold-water fisheries and for lakes and impoundments as shown in Table 2:

Table 2: Temperature Standards for Wisconsin Lakes and Cold-Water Streams (Wisconsin Administrative Code, Chapter NR 102)

Month	Maximum Temperature Standard (degrees Fahrenheit)		
	Ambient	Sub-Lethal	Acute
Lakes and Impoundments			
May	55	67	81
June	67	75	85
July	72	79	86
August	71	79	86
September	63	72	84
Streams - Cold Water Fisheries			
May	56	63	72
June	62	67	72
July	64	67	73
August	63	65	73
September	57	60	72

Ambient water quality is determined by a grab sample at a particular time and place, sub-lethal criteria are evaluated by weekly average maximum temperatures, and acute criteria are evaluated according to the daily maximum temperature.

Monitoring Results

15-Minute Dissolved Oxygen and Temperature Readings

Plots of dissolved oxygen concentration, water temperature, daily air temperature, percent dissolved oxygen saturation, and flow for the 2019 and 2020 seasons at each instrument location are included as Appendix A. Percent dissolved oxygen saturation was computed based on a barometric pressure of 750 mm Hg, representative of barometric pressures recorded at the Chanhassen, Minnesota NWS station.

The Appendix A plots also show the YSI grab sample readings.

Data Processing

Water temperatures recorded by the Hobo sensors and the YSI meter were consistent throughout the sampling seasons. At every location and every data download visit, the YSI dissolved oxygen reading at the time of retrieval and the initial Hobo reading after redeployment were also in good agreement. However, in some instances the dissolved oxygen concentrations recorded by the continuous Hobo sondes prior to retrieval did "drift" downward relative to the reading obtained at the end of the period with the YSI (and the reading obtained by the Hobo after cleaning). This was presumably due to sediment and/or algae impacting the Hobo sensor. Therefore, certain intervals in the 2020 Appendix A dissolved oxygen plots were corrected for drift. A drift adjustment was not applied to the 2019 data, because drift was not similarly apparent in the 2019 season.

The onset of the drift was identified visually by a shift in the plotted raw data typically beginning two or more days after the initial redeployment. The correction was a linear adjustment based on the difference between the last pre-retrieval Hobo reading, the YSI reading at the time of retrieval, and the first Hobo reading following cleaning and redeployment. Where possible the Hobo software's drift correction was used, but this did not always produce reasonable results. A "drift" period was then identified based on a visual inspection of the plotted raw data, and a correction was applied that increased linearly from zero at the beginning of the period to the measured offset (the difference between the last Hobo reading before retrieval and the first Hobo reading following cleaning and redeployment) at the end of the period.

In other instances, the Hobo records of dissolved oxygen concentration showed uncharacteristic patterns like sudden drops, large fluctuations, or flattened diurnal time series. However, these intervals did not lend themselves to a simple drift adjustment, either because there was not a consistent downward trend, or there was no significant disagreement with the YSI reading at the end of the recording period. These periods were plotted without adjustment, using a symbol flagging the data points as "suspect."

The following locations and periods in 2020 were adjusted using a linearly increasing drift correction factor, or were flagged as "suspect" data:

Project Inflow: No drift corrections; June 3-5, 2020, flagged as "suspect."

Lake George: Drift corrections May 24-29; June 1-11; June 14 -19; August 21-Sept 1, 2020; no "suspect" periods

Junction Falls Outflow: Drift correction May 19-20; missing data due to being removed from water May 29 –June 12; data flagged as suspect July 31 – August 6

Powell Falls Outflow: No drift corrections; flagged as suspect June 5 – 19, August 27 – 31, September 12 – 18; persistent issues with unit being displaced by public.

Summary of Seasonal Data

Table 3 summarizes the Hobo dissolved oxygen data in comparison to the above listed criteria, including the "suspect" readings from 2020. The applicable minimum dissolved oxygen concentration for cold water fisheries (trout streams) is 6 mg/L, as the study was conducted outside of the spawning season. Wisconsin's minimum dissolved oxygen concentration standard for lakes and impoundments is 5 mg/L.

Table 3: Summary of Recorded Dissolved Oxygen Concentrations

Location	Measured Dissolved Oxygen Range (mg/L) for Season	Percent of readings < 6.0 mg/L (trout stream standard)	Percent of readings < 5.0 mg/L (other water body standard)
Project Inflow	7.0 – 13.0 (2019) 1.4* – 14.5 (2020)	0 % 1.6%*	0 % 1.5%*
Lake George	0.0 – 13.0 (2019) 2.0 – 15.5 (2020)	37 % 12%	28 % 8%
Junction Falls Outflow	2.9 – 13.5 (2019) 2.4* – 12.4 (2020)	4 % 3%*	3 % 2 %*
Powell Falls Outflow	0.7 – 12.2 (2019) 0.0 – 15.0 (2020)	29 % 15%*	18 % 13%*
** lowest readings during period of "suspect" data*			

Tables 4 and 5 lists the maximum and average observed water temperatures by month, along with Wisconsin cold-water stream and lake criteria from Table 2. Temperatures representing periods in 2020 when the sensor was found to be removed from the water and recording air temperatures are omitted.

Table 4: Summary of Recorded Maximum 15 Minute (Acute) Temperatures

Month	Acute Water Temperature Criteria for Cold Water Stream/Lake, ºF		Maximum 15-minute Temperature, ºF			
	Stream	Lake	Project Inflow	Lake George	Junction Falls Outflow	Powell Falls Outflow
July 2019	73	86	64	78	78	80
Aug. 2019	73	86	63	65	65	82
Sept. 2019	72	84	63	62	63	66
May 2020	72	81	65	65	67	73
June 2020	72	85	65	68	69	72
July 2020	73	86	66	68	68	69
Aug. 2020	73	86	65	66	68	70
Sept. 2020	72	84	59	60	61	62

Table 5: Summary of Recorded Average Monthly (Ambient) Temperatures

Month	Ambient Water Temperature Criteria for Cold Water Stream/Lake, ºF		Monthly Average Water Temperature, ºF			
	Stream	Lake	Project Inflow	Lake George	Junction Falls Outflow	Powell Falls Outflow
July 2019	64	72	60	61	62	63
Aug. 2019	63	71	60	59	60	61
Sept. 2019	57	63	56	57	57	58
May 2020	56	55	57	57	58	59
June 2020	62	67	59	60	61	62
July 2020	64	72	61	62	63	63
Aug. 2020	63	71	59	60	61	62
Sept. 2020	57	63	54	54	55	55

Table 6 and Table 7, below, are provided to illustrate typical daily variations in time and space. Tables 6 and 7 provide “snapshots” of the monitor readings throughout the study reach at 4:00 a.m. and 4:00 p.m. at semi-monthly intervals. The same data are also included for the dates in each sampling season on which the highest water temperature and the lowest dissolved oxygen concentration were recorded downstream of Powell Falls Dam.

Table 6: Dissolved Oxygen Concentrations Through Study Reach, Selected Dates and Times

Date	Time	Dissolved Oxygen Concentration (mg/L)			
		Project Inflow	Lake George	Junction Falls Outflow	Powell Falls Outflow
July 20, 2019	4:00 a.m.	8.5	7.7	7.8	6.7
	4:00 p.m.	8.8	8.6	9.2	9.3
August 1, 2019	4:00 a.m.	N/A	6.3	7.6	7.7
	4:00 p.m.	N/A	7.6	11.1	9.2
August 10, 2019 *	4:00 a.m.	8.9	7.1	7.8	4.3
	4:00 p.m.	11.1	7.8	9.4	3.1
August 15, 2019	4:00 a.m.	8.7	6.6	8.4	5.4
	4:00 p.m.	11.1	8.8	11.2	4.9
August 31, 2019	4:00 a.m.	9.5	4.4	9.9	4.0
	4:00 p.m.	11.4	9.8	10.9	4.1
Sept. 15, 2019	4:00 a.m.	9.3	8.4	9.9	8.2
	4:00 p.m.	10.7	6.2	9.7	6.8
May 16, 2020	4:00 a.m.	9.6	9.6	9.8	10.8
	4:00 p.m.	14.0	12.5	11.7	12.6
June 1, 2020	4:00 a.m.	9.2	4.2	NA	9.3
	4:00 p.m.	10.9	9.2	NA	11.6
June 15, 2020	4:00 a.m.	9.3	5.7	10.0	3.9**
	4:00 p.m.	11.4	8.9	9.8	5.4**
July 18, 2020	4:00 a.m.	8.6	8.7	9.1	8.3
	4:00 p.m.	10.6	10.7	9.5	10.8
August 1, 2020	4:00 a.m.	8.8	9.0	7.8	8.3
	4:00 p.m.	10.5	11.2	8.6	10.3
August 6, 2020*	4:00 a.m.	9.0	9.0	4.8	5.0
	4:00 p.m.	12.0	12.9	9.9	12.6
August 15, 2020	4:00 a.m.	8.1	8.1	9.0	9.1
	4:00 p.m.	9.3	10.9	9.6	9.2
Sept. 1, 2020	4:00 a.m.	8.9	10.3	9.1	10.2
	4:00 p.m.	10.5	10.7	9.7	10.8
Sept 15, 2020	4:00 a.m.	9.3	9.2	9.7	0.6**
	4:00 p.m.	10.6	11.1	9.9	1.3**
Sept. 30, 2020	4:00 a.m.	9.6	9.4	9.9	9.4
	4:00 p.m.	10.8	11.0	10.1	11.6

* Date of minimum annual (reliable) recorded DO concentration at Powell Falls Outflow site

** Questionable reading but observed trends and/or YSI readings do not justify correction

Table 7: Water Temperatures Through Study Reach, Selected Dates and Times

Date	Time	Water Temperature (degrees Fahrenheit)			
		Project Inflow	Lake George	Junction Falls Outflow	Powell Falls Outflow
July 19, 2019*	4:00 a.m.	58	59	61	62
	4:00 p.m.	63	65	65	66
July 20, 2019	4:00 a.m.	60	61	63	64
	4:00 p.m.	60	61	62	63
August 1, 2019	4:00 a.m.	N/A	57	59	60
	4:00 p.m.	N/A	64	63	65
August 15, 2019	4:00 a.m.	58	58	60	60
	4:00 p.m.	61	62	63	64
August 31, 2019	4:00 a.m.	54	54	55	57
	4:00 p.m.	56	57	58	58
Sept. 15, 2019	4:00 a.m.	54	55	55	55
	4:00 p.m.	56	57	58	59
May 16, 2020	4:00 a.m.	54	54	54	56
	4:00 p.m.	56	56	57	57
June 1, 2020	4:00 a.m.	56	56	N/A	58
	4:00 p.m.	62	63	N/A	66
June 8, 2020*	4:00 a.m.	N/A	61	N/A	63
	4:00 p.m.	N/A	68	N/A	70
June 15, 2020	4:00 a.m.	57	57	57	59
	4:00 p.m.	60	60	62	62
July 18, 2020	4:00 a.m.	64	62	63	65
	4:00 p.m.	65	66	67	68
August 1, 2020	4:00 a.m.	58	58	59	60
	4:00 p.m.	60	61	62	63
August 15, 2020	4:00 a.m.	59	60	61	62
	4:00 p.m.	62	63	64	65
Sept. 1, 2020	4:00 a.m.	56	57	57	57
	4:00 p.m.	57	58	59	60
Sept. 15, 2020	4:00 a.m.	55	55	56	56
	4:00 p.m.	59	60	60	61
Sept. 30, 2020	4:00 a.m.	51	51	51	51
	4:00 p.m.	53	54	54	55
* Date of maximum annual (reliable) recorded water temperature at Powell Falls Outflow site					

Other Field Measurements

During the data download visits, grab samples using the YSI meter for dissolved oxygen and temperature were taken at the Hobo installation locations and (in 2020) at three additional sites in Lake George, as described in Figure 1b and Tables 8a – 8d. Additionally, the percent of algae cover on Lake George was visually estimated and photographed during each field visit. The data downloads and grab samples were always performed in the morning, usually between 9:00 and 11:00 a.m. A single YSI reading

approximately 0.5 to 1 foot below the water surface was recorded at the project inflow, Junction Falls outflow, and Powell Falls outflow. In Lake George, vertical and transect profiles were recorded in 2020 as shown in Table 8b. The three depth ranges shown in Table 8b for the 2020 readings represent the top, middle, and bottom of the water column at the four sample sites. Site LG-2 was the shallowest location in the transect, with a maximum depth of 1 foot, and site LG-1 was the deepest, with a maximum depth of 3 feet. The maximum sampling depths changed somewhat due to sediment transport and redeposition during and after the late June flood event.

Table 8a: YSI Meter Field Measurements at Project Inflow Site

Date	Dissolved Oxygen (mg/L)	Water Temperature (ºF)
Aug. 2, 2019	5.9 *	57
Aug. 13, 2019	10.4	55
Sept. 4, 2019	9.5	56
Sept. 17,2019	10.2	56
May 29, 2020	9.1	58
June 12, 2020	9.1	57
June 19, 2020	8.3	58
July 17, 2020	8.8	59
July 24, 2020	8.2	58
Aug. 6, 2020	9.2	56
Aug. 21, 2020	10.0	58
Sept. 1, 2020	9.7	56
Sept. 18, 2020	11.6	49
Sept. 25, 2020	10.6	58
**atypical for this site; reason for low reading is unknown. Reading was repeated 150' upstream with a similar result. Similar YSI reading (6.0 mg/L) was taken in Lake George on the same morning.*		

Table 8b: YSI Meter Field Measurements at Lake George Monitoring Site and Transect
(LG-2, LG-3, LG-4 numbered from northwest to southeast, Fig. 1b)

Date	Depth (ft)	Site LG-1 (Hobo Unit Location)		Site LG-2 (2 vertical pts before flood; 1 after)		Site LG-3 (3 vertical pts before flood; 2-3 after)		Site LG-4 (3 vertical pts)		Algae Cover %
		DO (mg/L)	Water Temp (ºF)	DO (mg/L)	Water Temp (ºF)	DO (mg/L)	Water Temp (ºF)	DO (mg/L)	Water Temp (ºF)	
July 18, 2019	0.5 - 1	5.2	61							50
Aug. 2, 2019	0.5 - 1	6.2	59							30
Aug. 13, 2019	0.5 - 1	10.2	58							25
Sept. 4, 2019	0.5 - 1	4.6	58							25
Sept. 17, 2019	0.5 - 1	9.1	58							15
May 29, 2020	0.5 1 - 1.5 1.5 - 3	8.6 8.7 8.6	57 57 57	8.9 8.7	57 57	9.2 9.2 9.4	58 58 58	8.3 8.9 8.4	61 61 58	0
June 12, 2020	0.5 1-1.5 1.5 - 3	8.2 8.0 7.7	56 56 56	8.2 8.2	57 57	8.7 8.6 8.4	57 57 57	7.2 7.1 7.3	59 57 57	10
June 19, 2020	0.5 1-1.5 1.5 - 3	7.9 7.7 7.6	58 58 58	7.9 7.9	59 59	8.0 8.4 8.0	59 59 59	6.4 6.4 6.9	61 61 60	10
July 17, 2020	0.5 1-1.5 1.5 - 3	8.6 8.4 8.3	59 59 59	7.6	63	7.1 7.7	61 60	7.3 7.0 7.4	65 65 60	20
July 24, 2020	0.5 1-1.5 1.5 - 3	8.3 8.2 7.8	59 58 59	7.8	63	7.7 8.4 8.4	62 60 60	6.7 6.5 7.6	63 62 60	20
Aug. 6, 2020	0.5 1-1.5 1.5 - 3	10.4 10.2 10.1	57 57 56	11.1	63	10.1 9.8 9.3	63 63 64	9.3 8.3 7.8	64 62 61	30
Aug. 21, 2020	0.5 1-1.5 1.5 - 3	9.7 9.6 9.7	59 59 59	9.2	65	10.4 9.6	65 64	10.5 10.4 10.6	66 64 63	35
Sept. 1, 2020	0.5 1-1.5 1.5 - 3	10.5 10.3 10.3	58 57 57	13.6	62	15.2 16.9	65 65	11.1 11.2	63 63	40
Sept. 18, 2020	0.5 1-1.5 1.5 - 3	10.7 10.5 10.4	49 49 49	11.7	52	13.0 13.5	53 53	13.5 14.4	55 55	40
Sept. 25, 2020	0.5 1-1.5 1.5 - 3	10.5 10.3 10.1	55 55 55	11.0	61	11.1 11.7	60 59	12.8 13.1	61 61	35

Table 8c: YSI Meter Field Measurements at Junction Falls Outflow Site

Date	Dissolved Oxygen (mg/L)	Water Temperature (ºF)
July 18, 2019	5.2	63
Aug. 2, 2019	7.3	60
Aug. 13, 2019	8.8	59
Sept. 4, 2019	7.1	57
Sept. 17,2019	7.9	59
May 29, 2020	9.1	62
June 12, 2020	9.0	56
June 19, 2020	8.5	60
July 17, 2020	8.8	60
July 24, 2020	8.6	60
Aug. 6, 2020	9.3	58
Aug. 21, 2020	10.3	60
Sept. 1, 2020	9.5	50
Sept. 18, 2020	11.7	57
Sept. 25, 2020	10.7	47

Table 8d: YSI Meter Field Measurements at Powell Falls Outflow Site

Date	Dissolved Oxygen (mg/L)	Water Temperature (ºF)
Jul 18, 2019	4.0	61
Aug. 2, 2019	6.9	62
Aug. 13, 2019	8.5	59
Sept. 4, 2019	6.2	58
Sept. 17,2019	6.8	59
May 29, 2020	9.1	59
June 12, 2020	9.3	58
June 19, 2020	9.0	61
July 17, 2020	8.9	60
July 24, 2020	8.9	61
Aug. 6, 2020	9.0	58
Aug. 21, 2020	10.5	62
Sept. 1, 2020	10	57
Sept. 18, 2020	11.8	50
Sept. 25, 2020	10.0	47

Summary and Comments

The following general observations are based on the data summarized above and plotted in Appendix A.

- Flows entering the project area from the upper (unregulated) Kinnickinnic River consistently met state criteria for cold water fisheries, with dissolved oxygen concentrations, dropping below 7 mg/L very rarely. Temperatures in 2019 were consistently below 60º F, characteristic of a baseflow-dominated stream, and in 2020 below 65º F, except during one interval when the unit had been disturbed and the probe near or above the water surface.
- From the upstream to the downstream limits of the study area, measured water temperatures typically increased by 2 to 4 degrees F on a given sampling day (Table 7).
- Measured dissolved oxygen concentrations generally decreased from upstream to downstream in the study area, although the amount of decrease was highly variable (Table 6).
- In Lake George, the dissolved oxygen concentration dropped below 5 mg/L on several occasions in 2019, reaching near-zero concentrations late in the season. The 2020 data showed low dissolved oxygen concentrations in Lake George as well as likely instrument drift due to fouling in May and June, but a return to more river-like conditions (as well as fewer sensor issues) after the late June flood. This may be attributable to the flood's flushing out of bed sediments and biological material.
- Moving away from the apparent flow path through Lake George (YSI sites LG-2, LG-3, and LG-4) the effects of impoundment are apparent in terms of higher temperatures and higher-amplitude daily dissolved oxygen cycles (Table 8b). Vertical stratification was minor or absent, although the southeastern transect locations appeared somewhat less thoroughly mixed than the Hobo unit location. Field personnel accessing sites LG-1, LG-2, LG-3, and LG-4 by boat reported that some current was detectable at all four sites.
- The plots in Appendix A show that dissolved oxygen concentrations at the three sites in or downstream of the dams' impoundments dropped below 6 mg/L during some periods in 2019. Below Powell Falls and in Lake George, these occurrences were recorded throughout the sampling season, falling below the Class 1 trout stream standard in 29 percent and 37 percent of measurements respectively (Table 3). Below Junction Falls, they were limited to the end of the sampling season, in a period which coincided with exceptionally low readings in Lake George as well. It should be noted that the Junction Falls outflow records were probably impacted some by inflows from the South Fork, although placement of the continuous monitors attempted to minimize these effects.
- In 2020, reliable dissolved oxygen measurements fell below the 6.0 mg/L standard less frequently than in 2019. Even including those considered questionable, the percentage of sub-standard readings below Powell Falls and in Lake George dropped to 15 percent and 12 percent, respectively.
- The 2019 sampling season did not include extreme hydrometeorological conditions. Streamflows throughout the study period were in approximately the top 30 percent of baseflows recorded for their respective months, based on the USGS gage period of record. The largest runoff event to occur during the 2019 sampling period peaked at 580 cubic feet per second, about 35 percent of the estimated two-year flood at the gage site (USGS Scientific Investigations Report 2016-5140) . Daily average temperatures were moderate, ranging from 55 ºF to 75 ºF.
- The 2020 sampling season was also relatively cool and wet. Not accounting for the very large flood event in late June, average daily flows throughout the season were higher than normal and

similar to those in 2019. Also like 2019, there were no periods of exceptionally high air temperatures during the sampling season.

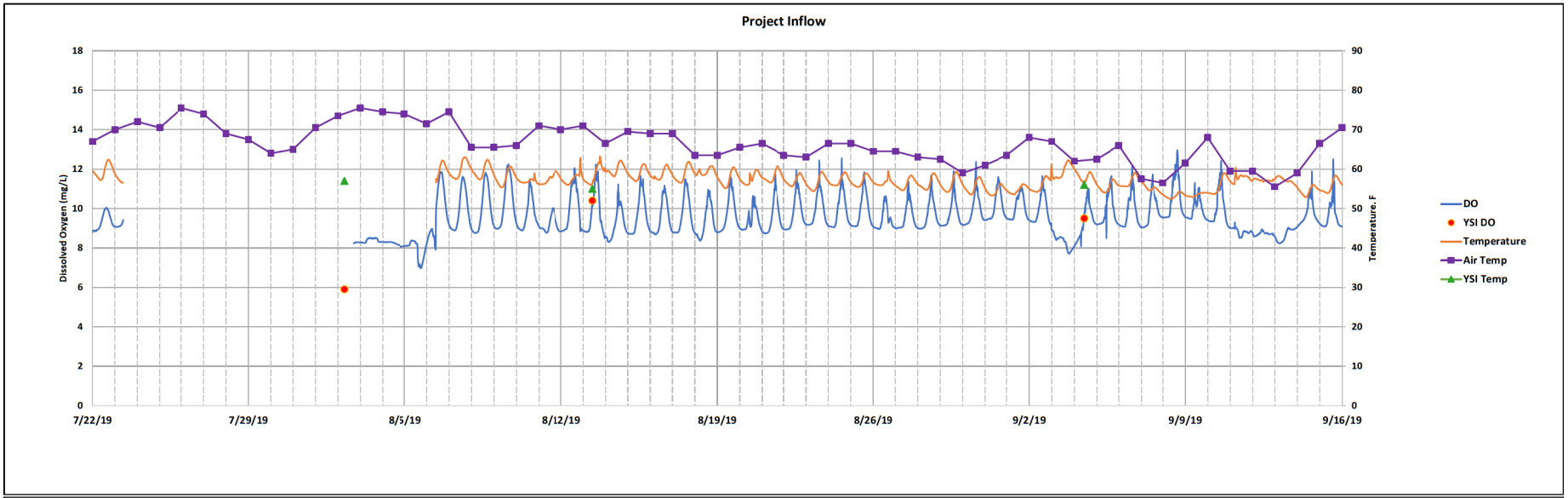
- The 2020 observations from Lake George and the Powell Falls outflow suggest that the June 29, 2020 flood may have led to a drop in the oxygen demand in the impoundments. The 2020 data from the Junction Falls outflow is inconclusive, as it is too discontinuous to support an assessment of the potential impacts of the June flood.

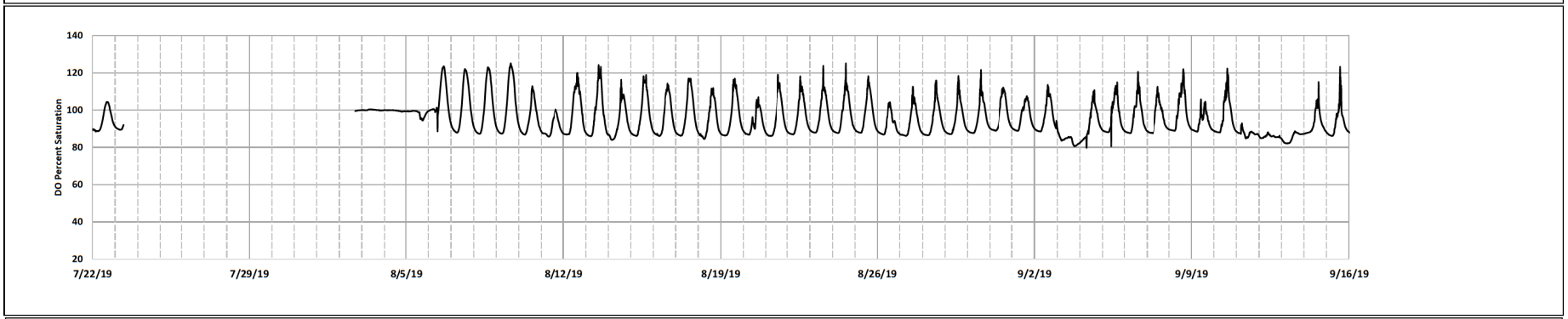
Appendix A

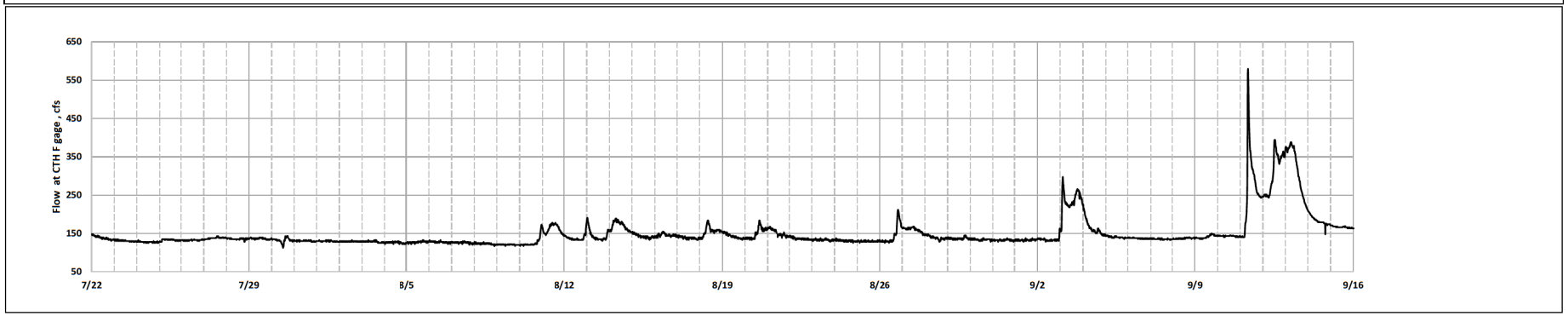
Data Time Series Plots

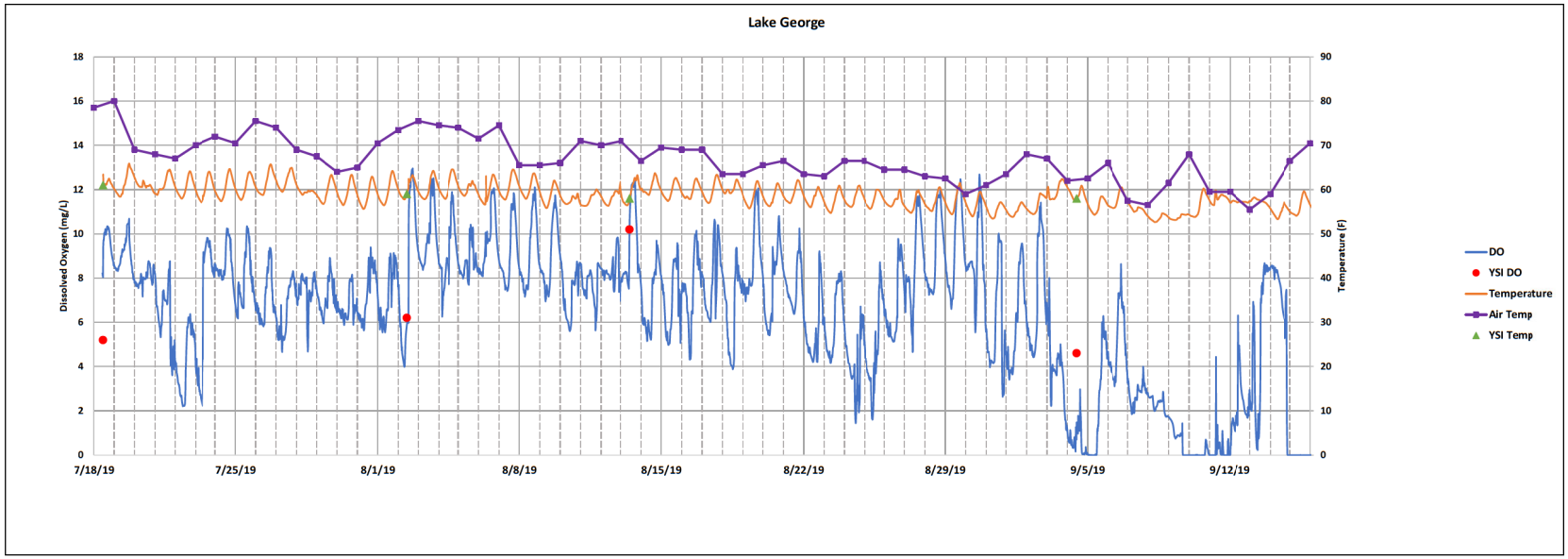
2019

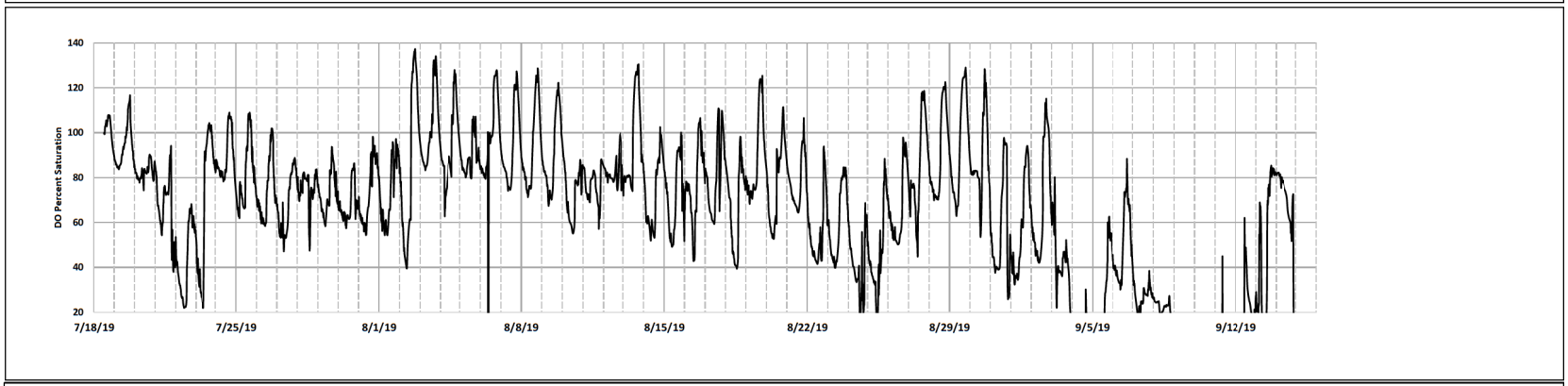
2020

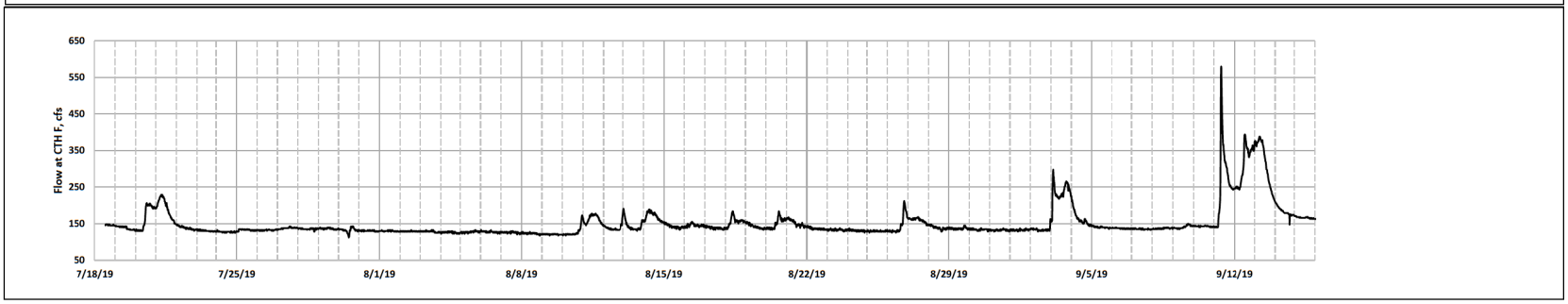

Project Inflow
Dissolved Oxygen (mg/L)
Temperature, F
7/22/19
7/29/19
8/5/19
8/12/19
8/19/19
8/26/19
9/2/19
9/9/19
9/16/19
DO
YSI DO
Temperature
Air Temp
YSI Temp

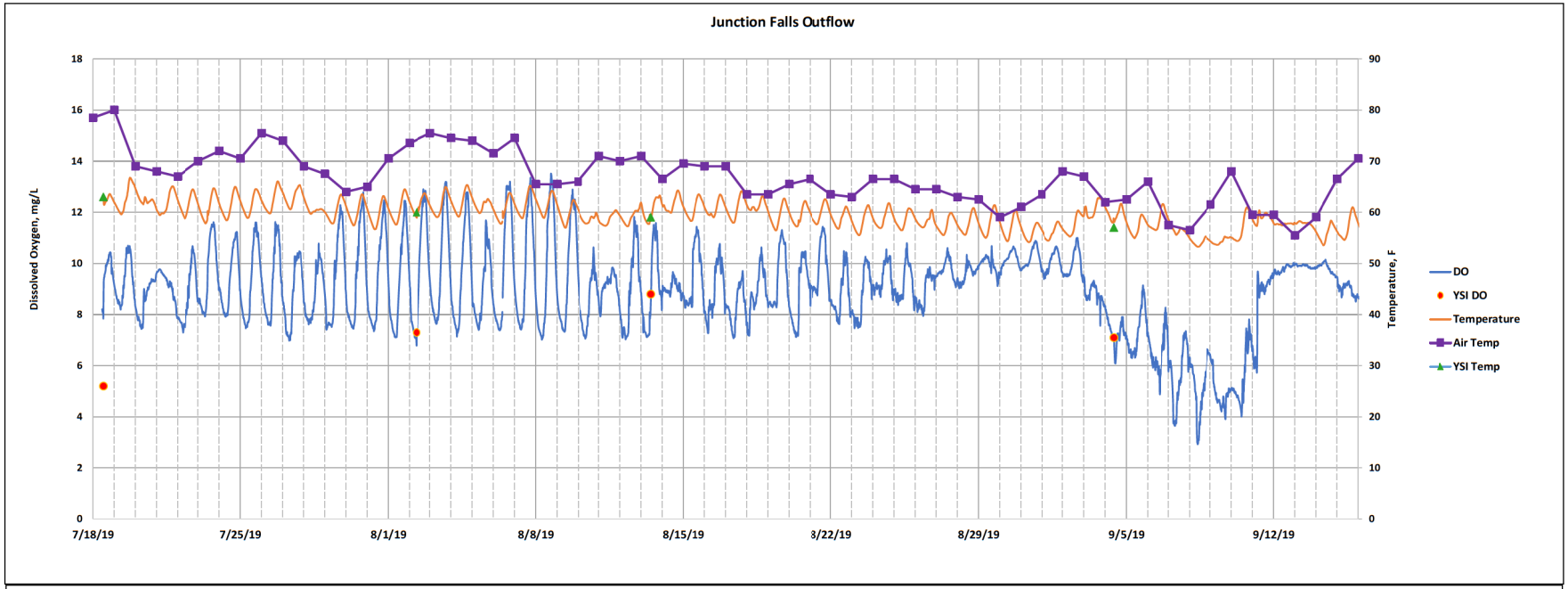

DO Percent Saturation
7/22/19
7/29/19
8/5/19
8/12/19
8/19/19
8/26/19
9/2/19
9/9/19
9/16/19

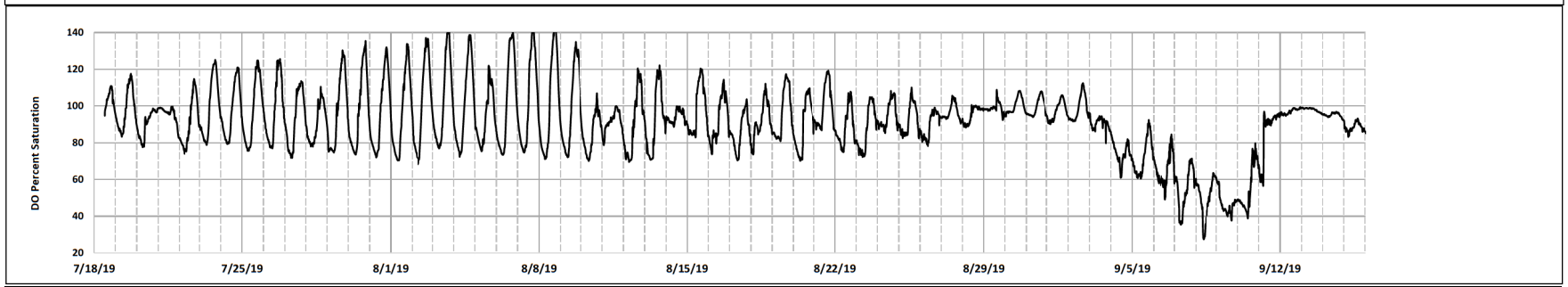

Flow at CTH F gage , cfs
7/22
7/29
8/5
8/12
8/19
8/26
9/2
9/9
9/16

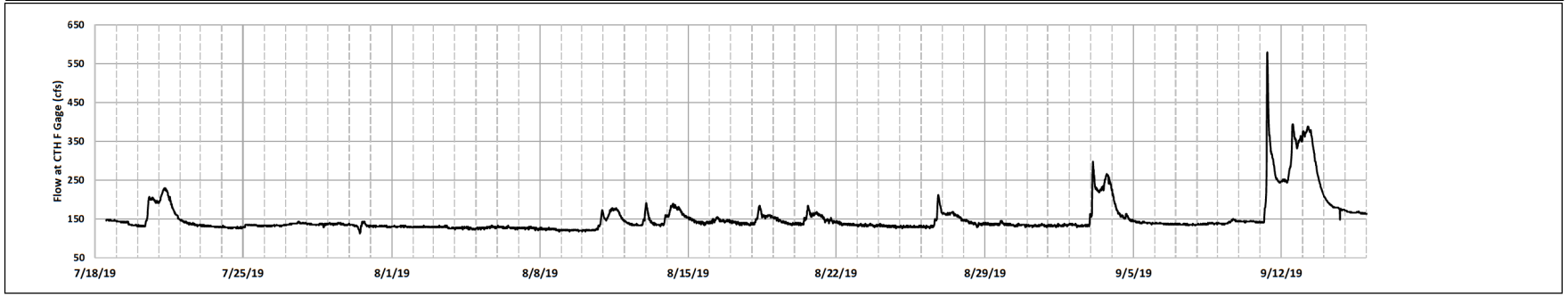

Lake George
Dissolved Oxygen (mg/L)
Temperature (F)
18
16
14
12
10
8
6
4
2
0
90
80
70
60
50
40
30
20
10
0
7/18/19
7/25/19
8/1/19
8/8/19
8/15/19
8/22/19
8/29/19
9/5/19
9/12/19
DO
YSI DO
Temperature
Air Temp
YSI Temp

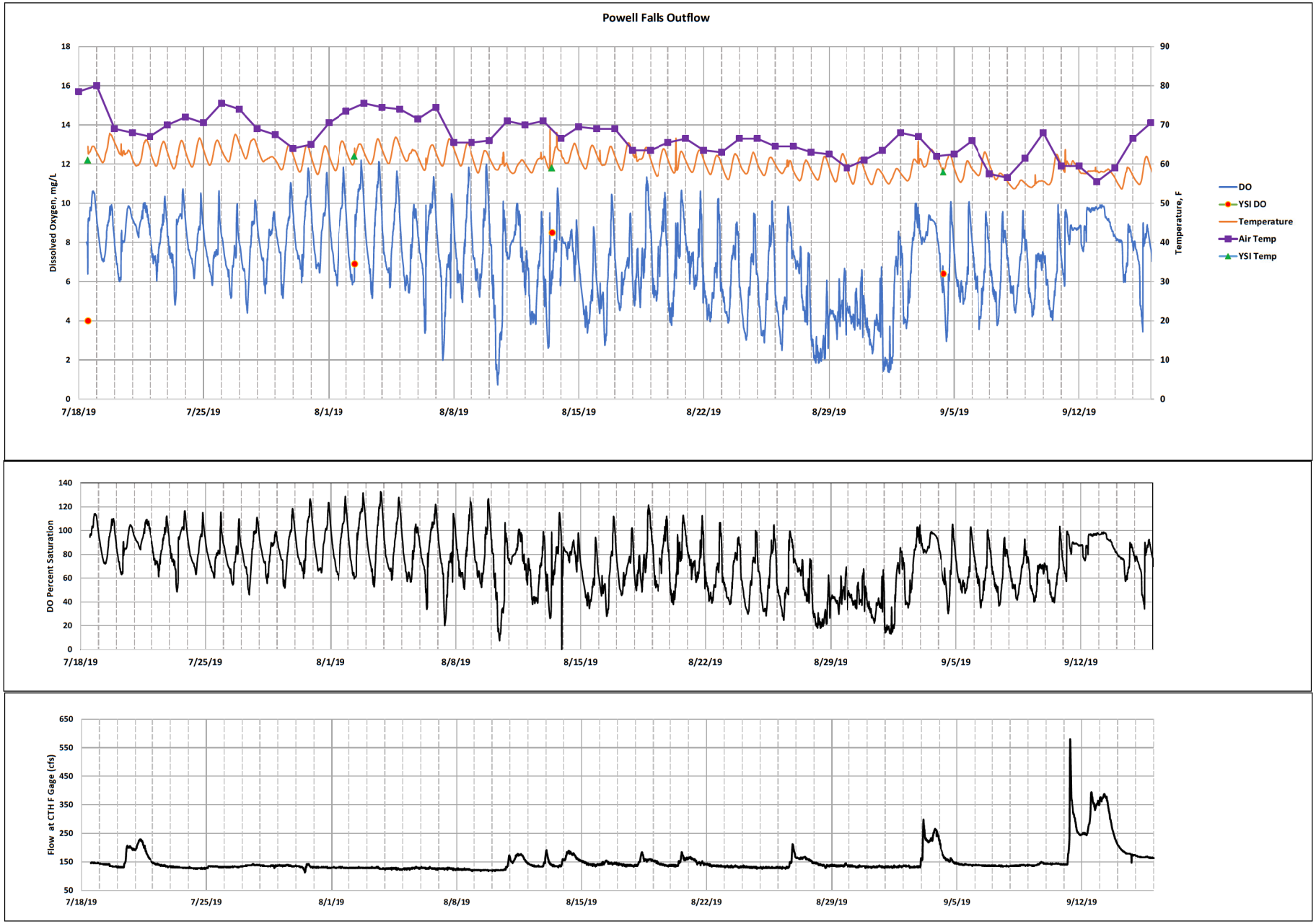

DO Percent Saturation
140
120
100
80
60
40
20
7/18/19
7/25/19
8/1/19
8/8/19
8/15/19
8/22/19
8/29/19
9/5/19
9/12/19


Flow at CTH F, cfs
650
550
450
350
250
150
50
7/18/19
7/25/19
8/1/19
8/8/19
8/15/19
8/22/19
8/29/19
9/5/19
9/12/19

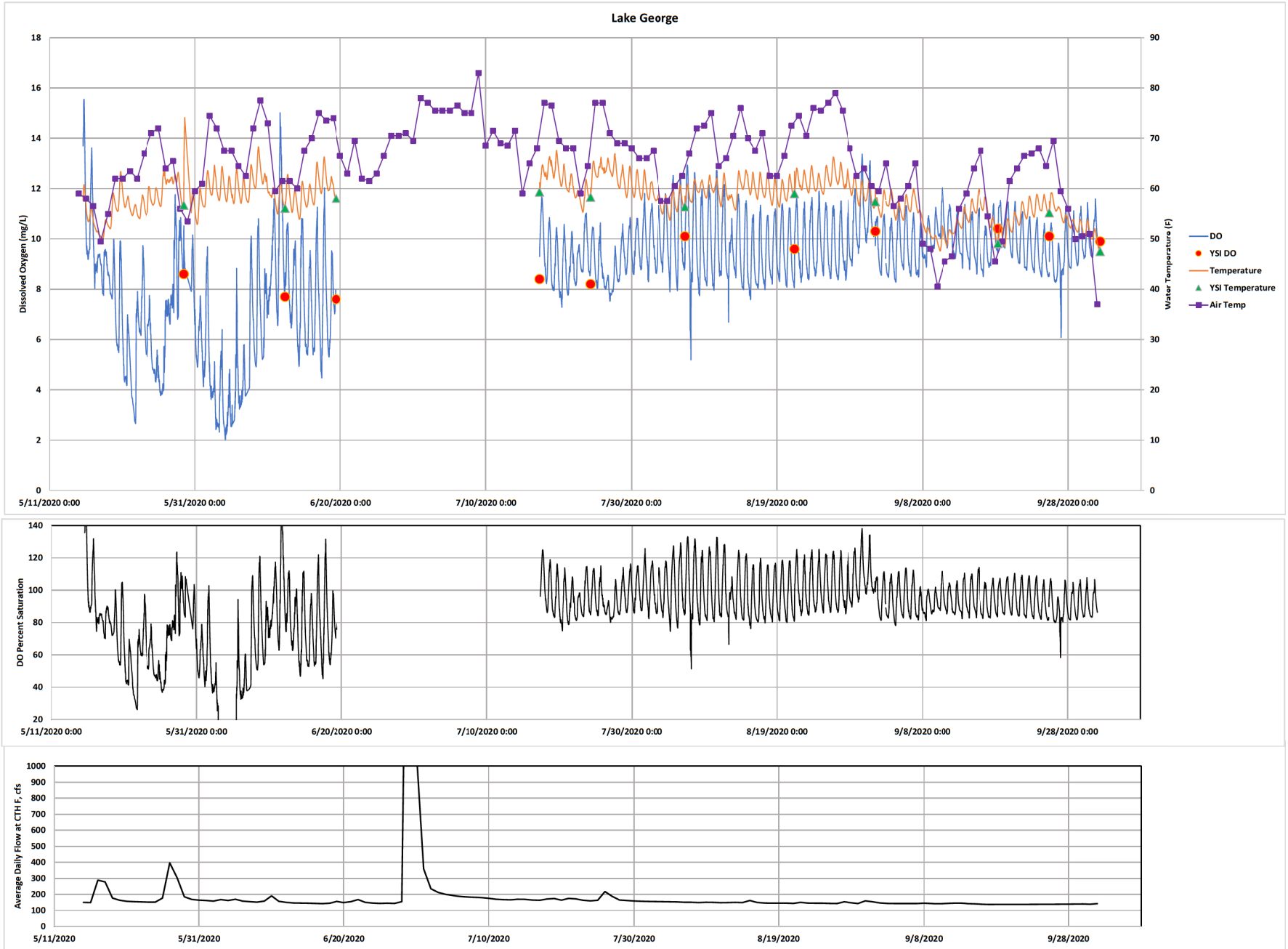

Junction Falls Outflow
Dissolved Oxygen, mg/L
Temperature, F
DO
YSI DO
Temperature
Air Temp
YSI Temp
7/18/19
7/25/19
8/1/19
8/8/19
8/15/19
8/22/19
8/29/19
9/5/19
9/12/19

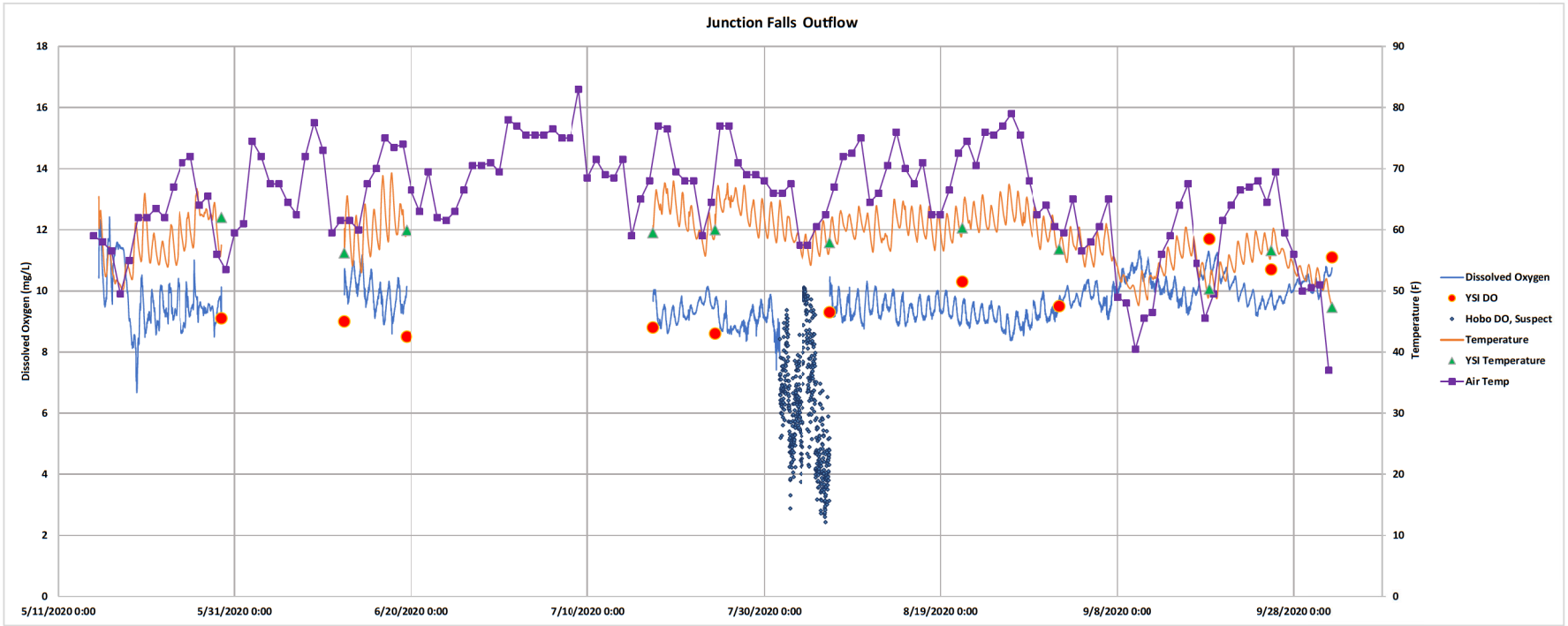

DO Percent Saturation
7/18/19
7/25/19
8/1/19
8/8/19
8/15/19
8/22/19
8/29/19
9/5/19
9/12/19

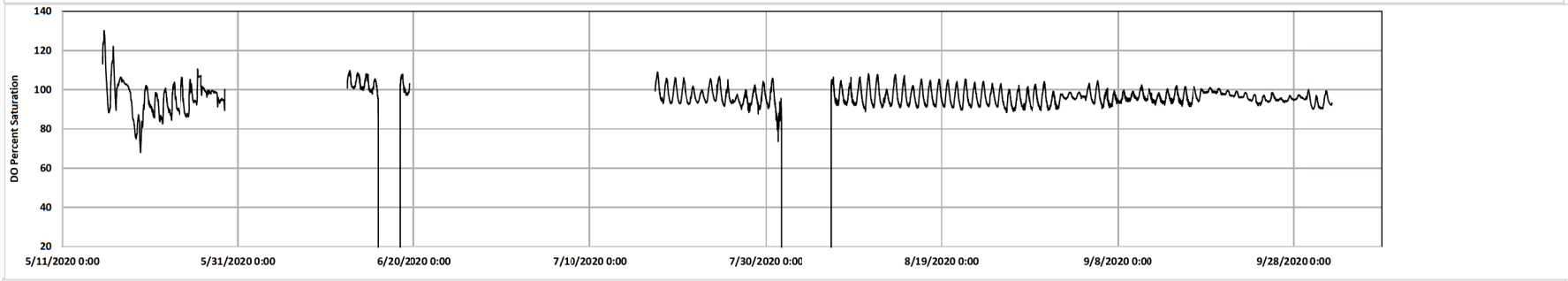

Flow at CTH F Gage (cfs)
7/18/19
7/25/19
8/1/19
8/8/19
8/15/19
8/22/19
8/29/19
9/5/19
9/12/19

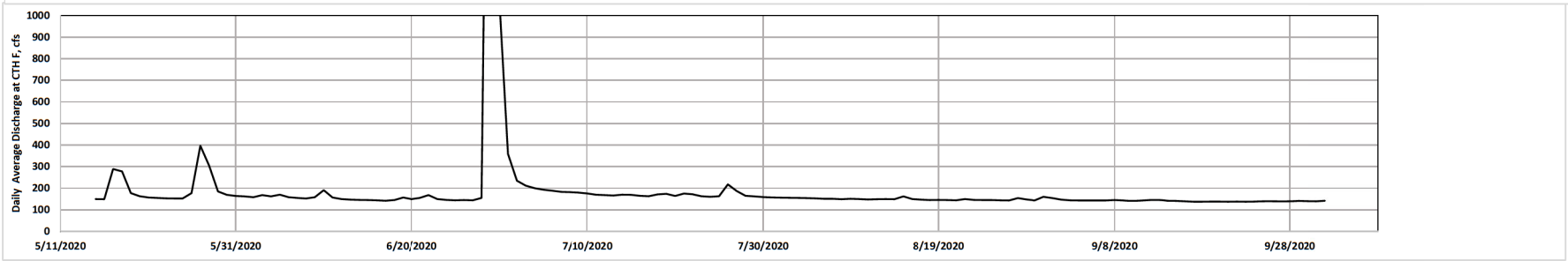

Powell Falls Outflow
Dissolved Oxygen, mg/L
Temperature, F
DO
YSI DO
Temperature
Air Temp
YSI Temp
DO Percent Saturation
Flow at CTH F Gage (cfs)
7/18/19
7/25/19
8/1/19
8/8/19
8/15/19
8/22/19
8/29/19
9/5/19
9/12/19

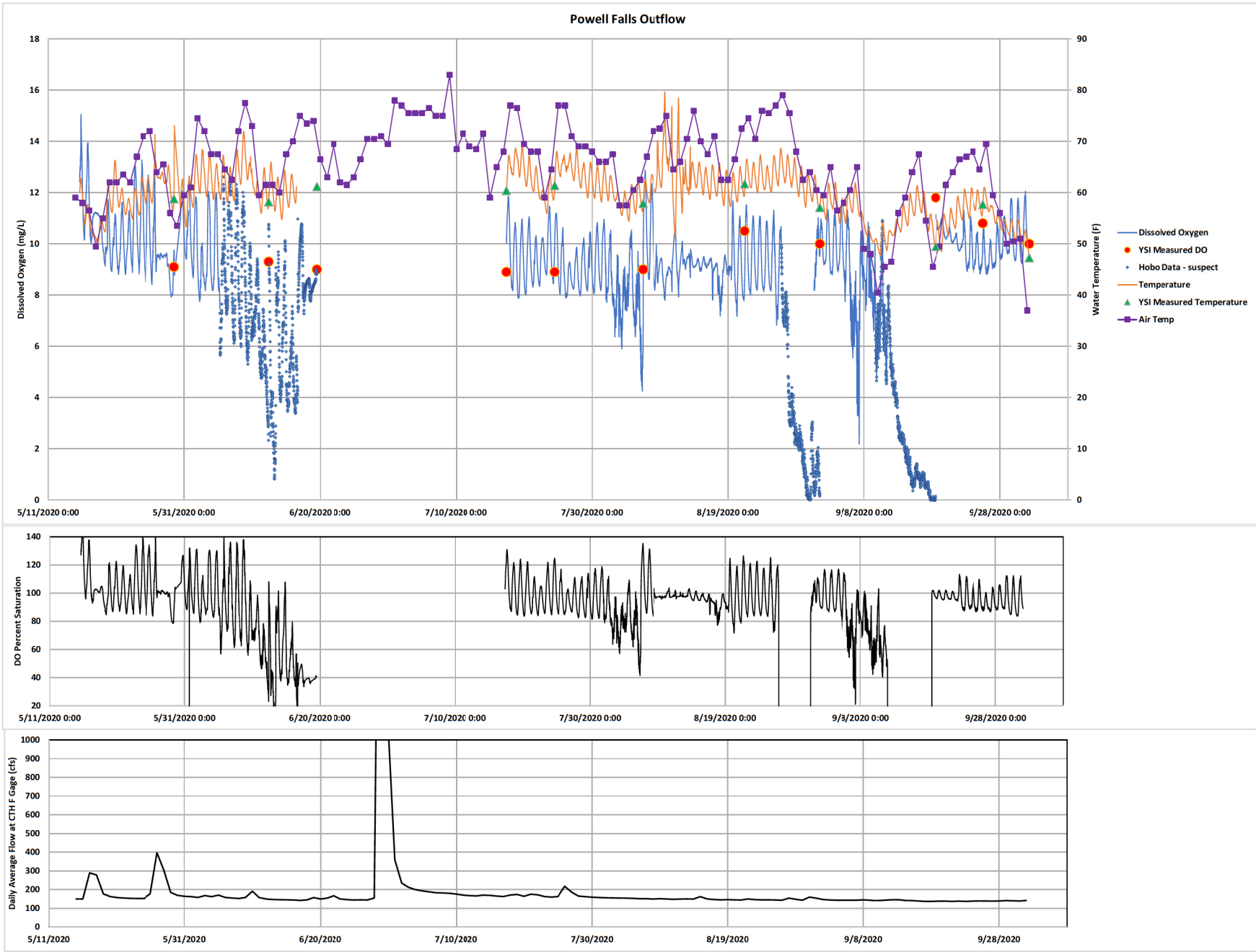

Project Inflow
Dissolved Oxygen (mg/L)
Temperature (F)
Dissolved Oxygen
YSI DO
Hobo DO, suspect
Temperature
YSI Temperature
Air Temp
5/11/2020 0:00
5/31/2020 0:00
6/20/2020 0:00
7/10/2020 0:00
7/30/2020 0:00
8/19/2020 0:00
9/8/2020 0:00
9/28/2020 0:00
DO percent saturation
Daily Average Flow at CTH F, cfs
5/11/2020
5/31/2020
6/20/2020
7/10/2020
7/30/2020
8/19/2020
9/8/2020
9/28/2020


Lake George
Dissolved Oxygen (mg/L)
Water Temperature (F)
DO
YSI DO
Temperature
YSI Temperature
Air Temp
5/11/2020 0:00
5/31/2020 0:00
6/20/2020 0:00
7/10/2020 0:00
7/30/2020 0:00
8/19/2020 0:00
9/8/2020 0:00
9/28/2020 0:00
DO Percent Saturation
Average Daily Flow at CTH F, cfs
5/11/2020
5/31/2020
6/20/2020
7/10/2020
7/30/2020
8/19/2020
9/8/2020
9/28/2020


Junction Falls Outflow
Dissolved Oxygen (mg/L)
Temperature (F)
Dissolved Oxygen
YSI DO
Hobo DO, Suspect
Temperature
YSI Temperature
Air Temp
5/11/2020 0:00
5/31/2020 0:00
6/20/2020 0:00
7/10/2020 0:00
7/30/2020 0:00
8/19/2020 0:00
9/8/2020 0:00
9/28/2020 0:00


DO Percent Saturation
5/11/2020 0:00
5/31/2020 0:00
6/20/2020 0:00
7/10/2020 0:00
7/30/2020 0:00
8/19/2020 0:00
9/8/2020 0:00
9/28/2020 0:00


Daily Average Discharge at CTH F, cfs
5/11/2020
5/31/2020
6/20/2020
7/10/2020
7/30/2020
8/19/2020
9/8/2020
9/28/2020


Powell Falls Outflow
Dissolved Oxygen (mg/L)
Water Temperature (F)
Dissolved Oxygen
YSI Measured DO
Hobo Data - suspect
Temperature
YSI Measured Temperature
Air Temp
5/11/2020 0:00
5/31/2020 0:00
6/20/2020 0:00
7/10/2020 0:00
7/30/2020 0:00
8/19/2020 0:00
9/8/2020 0:00
9/28/2020 0:00
DO Percent Saturation
Daily Average Flow at CTH F Gage (cfs)
5/11/2020
5/31/2020
6/20/2020
7/10/2020
7/30/2020
8/19/2020
9/8/2020
9/28/2020