Technical Memorandum

Date: November 4, 2020

To: Demian Ebert, PacifiCorp

Copies: <n/a>

From: Brooke Mejica, Watercourse Engineering, Inc.
Mike Deas, Watercourse Engineering, Inc.

Re: Summary of Dissolved Oxygen Monitoring in the Klamath River Downstream of Iron Gate Dam in 2019

1. Introduction

In 2012, PacifiCorp prepared the *Klamath Hydroelectric Project Interim Operations Habitat Conservation Plan for Coho Salmon* (HCP). The National Marine Fisheries Service (NMFS) issued an incidental take permit for Coho to PacifiCorp in February 2012 following review of the HCP and preparation of a biological opinion and environmental assessment. The incidental take permit authorizes take of Coho Salmon per Section 10(a)(1)(B) of the Endangered Species Act but requires reporting, monitoring, and evaluation of two surrogates for levels of take. One of the surrogates for take of Coho Salmon has to do with dissolved oxygen (DO) concentrations downstream of Iron Gate Dam. The surrogate for indicating whether the authorized level of incidental take is exceeded is if decreases in DO concentrations that fall below 85 percent saturation[1] downstream of Iron Gate Dam for longer than 7 consecutive days in the 6 miles of river downstream of Iron Gate Dam during the period from June 15 to September 30 when over-summer rearing juvenile Coho Salmon are present (NMFS 2012). The 6 miles of the Klamath River from Iron Gate Dam downstream to the Klamathon Bridge are the study reach for this effort.

In 2015, PacifiCorp installed an intake barrier curtain in Iron Gate Reservoir that segregates surface water in the reservoir and results in the entrainment of deeper, cooler, water into the powerhouse intake that is then released into the Klamath River. The water from deeper in Iron Gate Reservoir also has lower DO concentrations than the surface waters. Operations of the curtain from 2016-2018 made it clear that achieving DO concentrations in compliance with the take surrogate while also effectively limiting the release of cyanobacteria into the Klamath River downstream of Iron Gate Dam were in

[1] The 85 percent saturation value is site-specific, and is calculated with water temperatures and site-specific barometric pressure and salinity as described in NCWQCB (2010, Table 3.1a).

conflict. This study was conducted in 2019 to better understand the DO dynamics in the river downstream of Iron Gate Dam.

This evaluation includes DO data collected as part of ongoing monitoring of the Klamath River downstream of Iron Gate Dam, the deployment of continuous DO probes, and two longitudinal boat surveys. Included herein is a conceptual-level discussion of DO dynamics in the Klamath River downstream of Iron Gate Dam (Section 2), 2019 monitoring results (Section 3), a discussion of the role of mechanical reaeration (Section 4), and conclusions and recommendations (Section 5). Appendix A includes the monitoring plan and Appendix B presents 2019 and pre-2019 data downstream of Iron Gate Dam.

2. Klamath River Dissolved Oxygen Dynamics

Dissolved oxygen concentrations in river systems depend on numerous factors, including stream depth and velocity, temperature, primary production (photosynthesis and respiration), biochemical oxygen demand (BOD, NBOD), sediment oxygen demand (SOD), and DO of inflows (from upstream reaches, tributaries, groundwater, discharges and their associated oxygen demands, if any) (Figure 1). The balance of these processes and interactions determine DO concentrations in water at any given time.

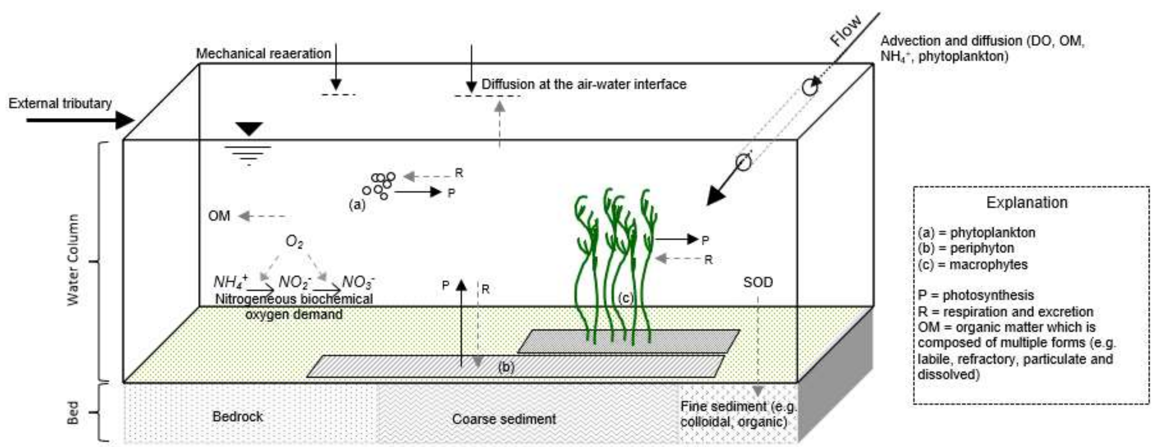


Figure 1. General processes and factors affecting dissolved oxygen in a river reach.

In the Klamath River downstream of Iron Gate Dam, diel DO variation occurs in response to primary production (seasonally), water temperature, changes in release water quality from the dam, and mechanical reaeration. Mechanical reaeration in the Klamath River in this reach was estimated using field data collected in 2019 and compared to empirical calculations (Section 4).

Given the eutrophic nature of the Klamath River, notable seasonal primary production, DO concentrations in releases from Iron Gate Dam, and shallow riverine conditions, many of the factors listed above play a role in DO dynamics in the study reach. Based on previous field efforts, deployment of remote recording DO sensors was deemed an appropriate method to capture river DO conditions in space and time.

3. Monitoring Results

Prior to conducting 2019 field work, a monitoring plan (Appendix A) was developed and a reconnaissance trip was completed to identify monitoring locations and test deployment techniques. Outlined herein are the monitoring locations, and findings of the continuous DO monitoring and longitudinal surveys.

3.1. 2019 Dissolved Oxygen Monitoring Data

Klamath River DO monitoring downstream of Iron Gate Dam in 2019 included two data sondes that record DO (mg/L and percent saturation) data as well as installation of seven Onset U-26 DO meters that record DO (mg/L) at sites downstream of Iron Gate Dam to the Klamathon Bridge, approximately 5.6 river miles downstream of Iron Gate Dam (Figure 2 and Table 1). A longitudinal survey was conducted in each of August and September that collected high resolution DO data approximately every 0.05 river mile (mg/L and percent saturation) from Lakeview Road Bridge to the Klamathon Bridge.

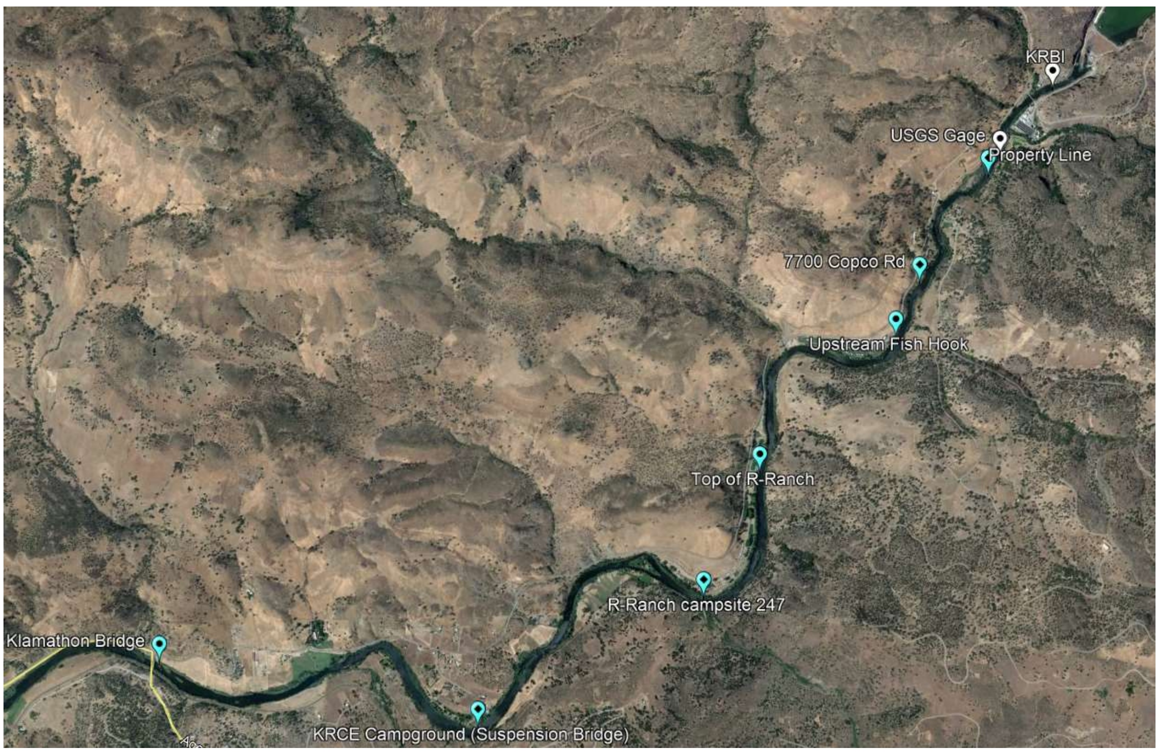


Figure 2. Locations of data sondes (white) and Onset U-26 continuous DO monitors (blue) downstream of Iron Gate Dam, 2019.

Table 1. Site name, approximate river mile downstream of Iron Gate Dam, latitude and longitude, and site descriptions for data sondes and Onset U-26 meters installed in the Klamath River downstream of Iron Gate Dam, 2019.

Site	Approximate RM downstream of Iron Gate Dam	latitude	longitude	Site Description
KRBI	0.2	41.931317	-122.440959	PacifiCorp sonde location above Lakeview Road Bridge, river left
USGS/Karuk	0.5	41.927808	-122.443944	Karuk sonde at USGS site near Iron Gate Fish Hatchery, river left
Property Line	0.6	41.926700	-122.444800	First accessible site upstream from PacifiCorp property line, river left
7700 Copco Rd	1.2	41.920655	-122.450030	At downstream end of 7700 Copco, at property line, river right
Upstream of Fish Hook	1.4	41.917580	-122.451830	At upstream end of the Blue Heron RV Park property, river right
Top of R-Ranch	2.4	41.909927	-122.462209	At upstream end of the R-Ranch property, near the lodge, river right
R-Ranch site 247	3.0	41.902800	-122.466500	Adjacent to campsite 247, also accessible from R-Ranch beach near fish cleaning station, river right
KRCE Campground	4.2	41.895442	-122.483738	Directly upstream of the KRCE Campground suspension bridge, river right
Klamathon Bridge	5.6	41.899136	-122.508103	Upstream of the Montague (Klamathon) bridge, river right.

3.1.1. Continuous Monitoring Data

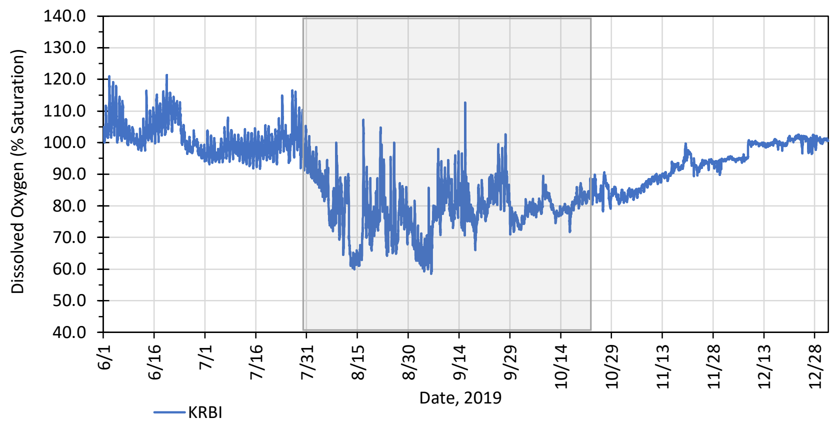
Onset U-26 DO meters collected DO (mg/L) data at 15-minute intervals from July 30 or 31 through October 23 or 24, 2019[2]. U-26 DO data were corrected for biofouling using DO data collected with a secondary YSI Professional Plus meter during site visits and Onset's Dissolved Oxygen Assistant software. Dissolved oxygen data (mg/L) were converted to percent saturation using the Onset Dissolved Oxygen Assistant and represent site-specific (local) percent saturation[3]. In addition to the seven sites with U-26 meters, DO (mg/L and percent saturation) data were collected at 15-minute intervals with YSI EXO data sondes in the Klamath River downstream of Iron Gate Dam [PacifiCorp sonde at Klamath River Below Iron Gate (KRBI) site and Karuk sonde at USGS gage

[2] U-26 meters were installed at Upstream Fish Hook, Top of R-Ranch, and KRCE on July 30, 2019 and at Property Line, 7700 Copco, R-Ranch 247, and Klamathon Bridge on July 31, 2019. Equipment was removed from Property Line, 7700 Copco, KRCE, and Klamathon Bridge on October 23, 2019 and from upstream of Fish Hook, Top of R-Ranch, and R-Ranch 247 on October 24, 2019.

[3] DO percent saturation was calculated with 15-minute water temperatures from U-26 DO meters, 15-minute site-specific barometric pressures from the Iron Gate Dam meteorological station, and specific conductance from the Klamath River Below Iron Gate (KRBI) sonde averaged over the period that U-26 DO meters were deployed (141.4 μS/cm).

site[4]] (Figure 3). 2019 data from the PacifiCorp (KRBI) and Karuk data sonde sites are included for comparison.

Dissolved oxygen concentrations in releases from Iron Gate Dam experience seasonal reduction in concentrations associated with low DO conditions in Iron Gate Reservoir. Reduced concentrations coincide with stratification and seasonal algae production in the reservoir, which starts in July and extends into October (Figure 3).



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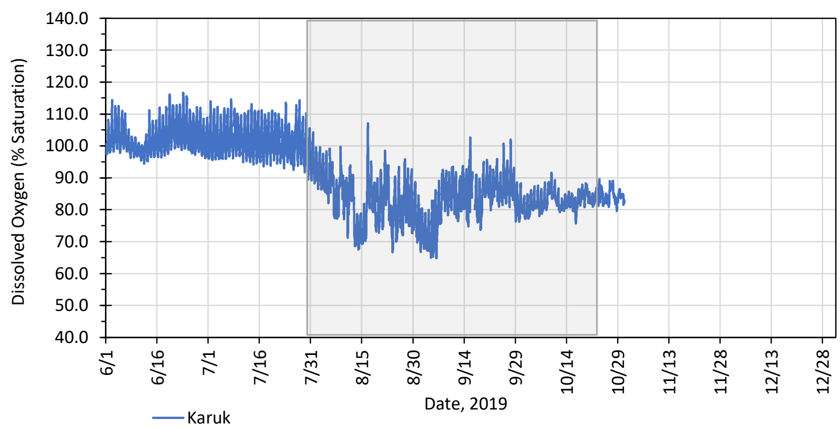


(b)

Figure 3. Dissolved oxygen (percent saturation) data from (a) the PacifiCorp data sonde approximately 0.2 river miles downstream from Iron Gate Dam, June 1 through December 31, 2019 and (b) the Karuk data sonde approximately 0.5 river miles downstream from Iron Gate Dam, June 1 through October 31, 2019. Grey boxes denote the period that data were also collected with Onset U-26 meters at additional sites downstream of Iron Gate Dam.

[4] Dissolved oxygen concentrations (mg/L) were provided with water temperatures from the Karuk data sonde site. Site-specific dissolved oxygen percent saturation (local) values were calculated from these data and site-specific barometric pressure data.

During the monitoring period, DO concentrations, percent saturation, and diel ranges generally increased in the downstream direction, particularly in the four most downstream sites (Figure 4 and Figure 5).

As distance downstream of Iron Gate Dam increases, the signature of the reservoir diminishes and DO concentrations and percent saturation begin to take on characteristics consistent with the shallow, moderate channel gradient, and macrophyte-dominated river. This is apparent as an increased, fairly uniform diel DO range that exhibits a longer-term (seasonal) trend. This diel range increases with distance from the dam due to the accumulated contributions of DO associated with photosynthesis. Maximum daily concentrations increase in the downstream direction, while minimum daily concentrations are similar across sites (Figure 6). Primary production and mechanical reaeration both contribute to DO conditions. Percent saturation mirrors concentrations and illustrate both sub and supersaturation conditions (Figure 7).

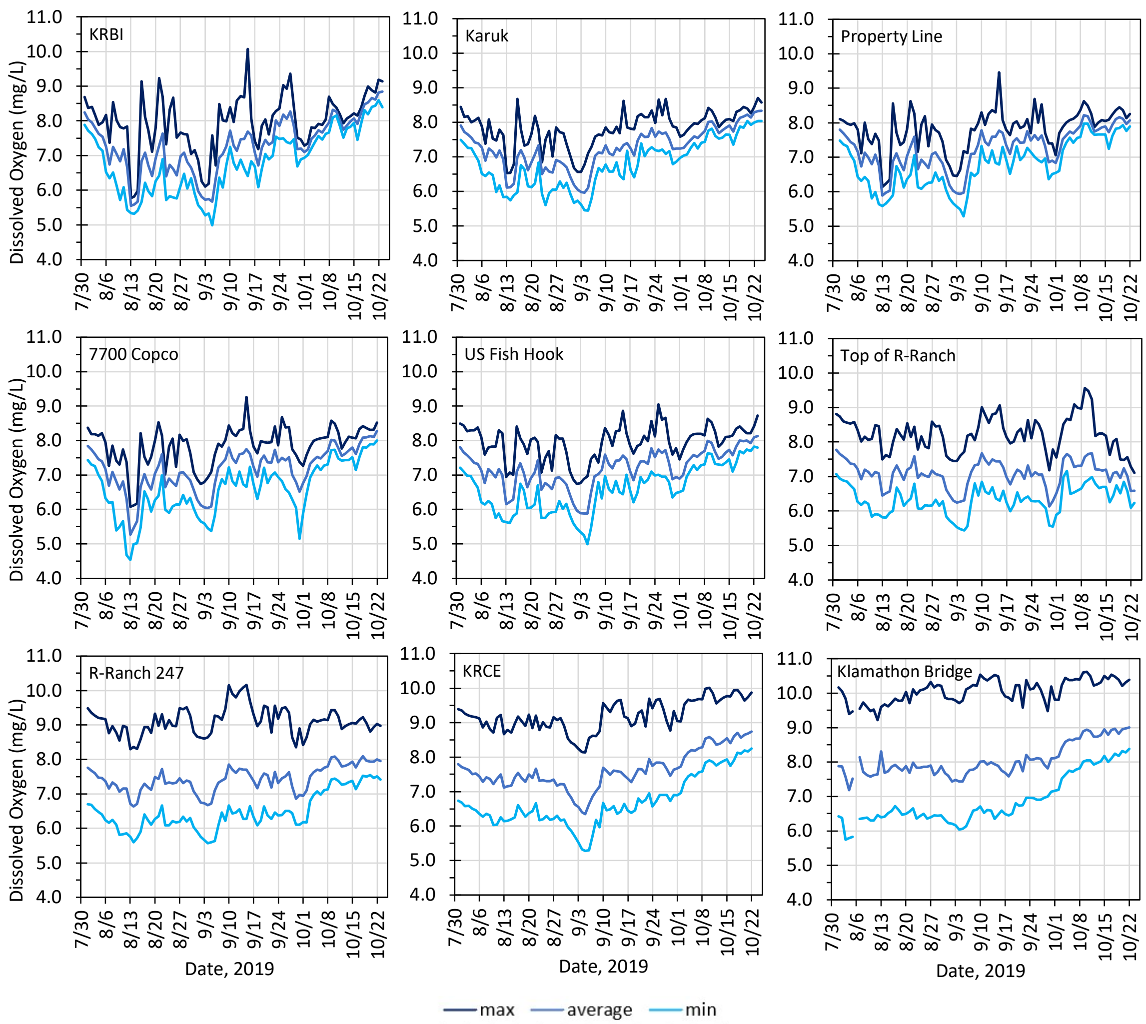


Figure 4. Daily maximum, average, and minimum dissolved oxygen (mg/L) data downstream of Iron Gate Dam: July 30 through October 24, 2019.

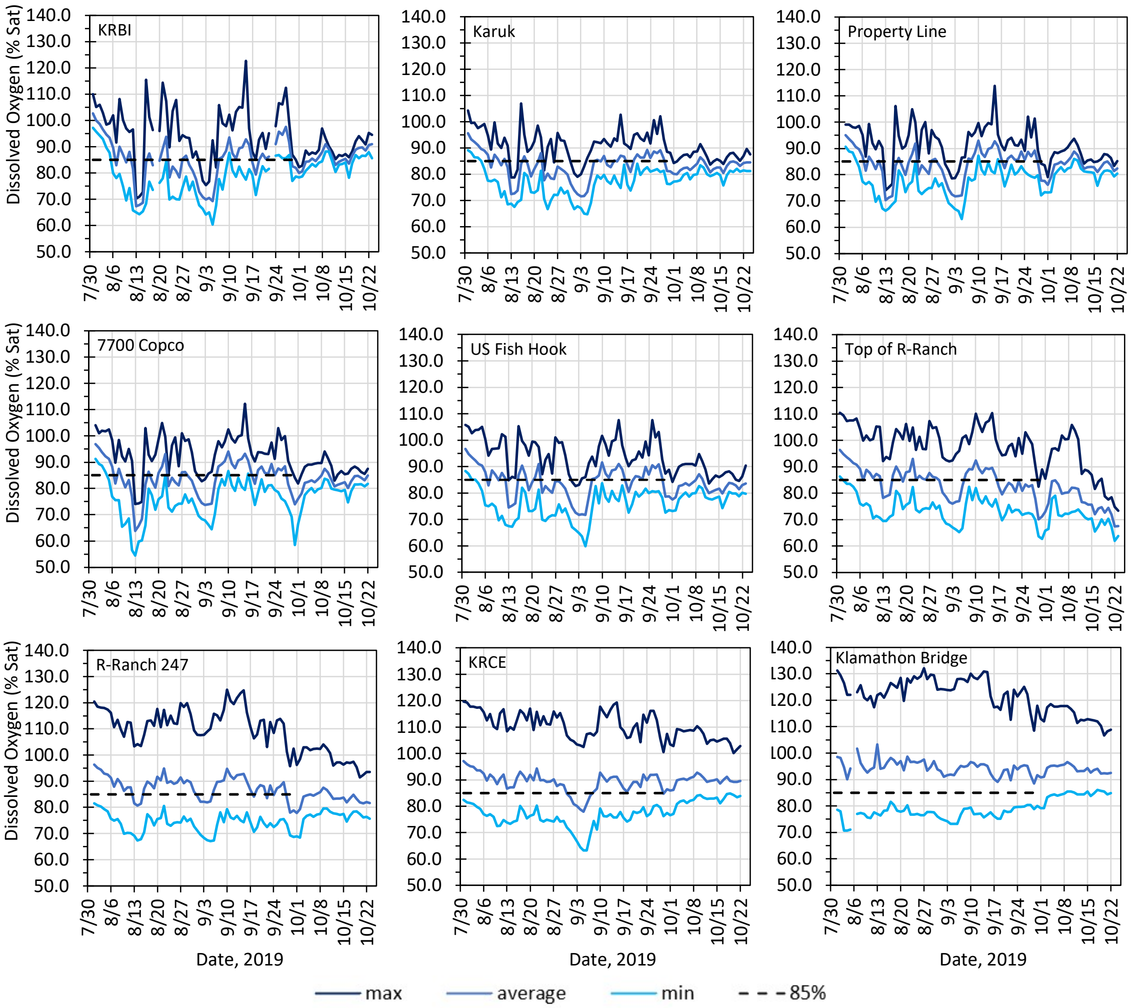


Figure 5. Daily maximum, average, and minimum dissolved oxygen (percent saturation) data through the study reach downstream of Iron Gate Dam and 85 percent saturation threshold (dashed line): July 30 through October 24, 2019.

During the period monitored (July 31 through October 23, 2019), DO concentrations in the study reach downstream of Iron Gate Dam ranged from 4.5 to 11 mg/L, and percent saturation ranged from 55 to 132, with the lowest DO concentrations occurring on August 13 at the 7700 Copco Road site (Figure 6 and Figure 7). This corresponded to the day after the Iron Gate Reservoir barrier curtain was deployed to a depth of 6.1 m (Table 2). Maximum daily DO percent saturation often reached 85 percent at all sites downstream of Iron Gate Dam during the period monitored (Figure 7). At river mile 2.4 downstream of the dam (Top of R-Ranch), maximum daily DO was only below 85 percent saturation for 1 day at the end of September, and for 7 days in late October, outside the ITP take surrogate monitoring period (Figure 7). Maximum daily DO concentrations and percent saturation continued to increase in the downstream direction (Figure 6 and Figure 7). Dissolved oxygen reached 85 percent saturation at least once per day for each day at river mile 3.0 downstream of the dam (R-Ranch site 247) (Figure 7). Maximum daily DO percent saturation was never less than 100 percent at KRCE (4.2 river miles below Iron

Gate Dam) and never less than 106 percent at the Klamathon Bridge (5.6 river miles below Iron Gate Dam) (Figure 7).

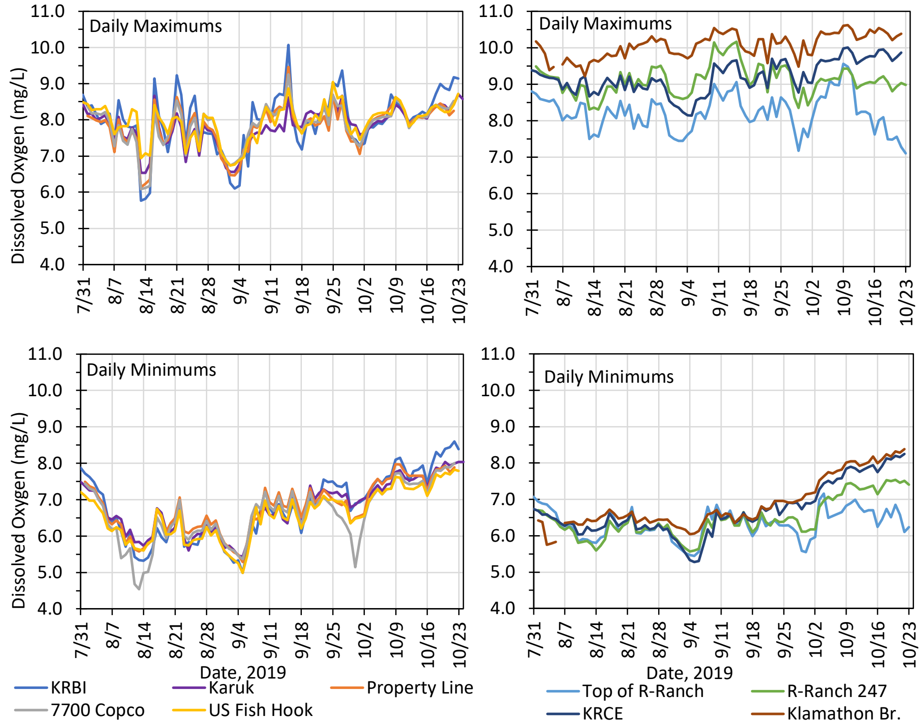


Figure 6. Daily minimum and maximum dissolved oxygen (mg/L) data through the study reach downstream of Iron Gate Dam: July 31 through October 23, 2019.

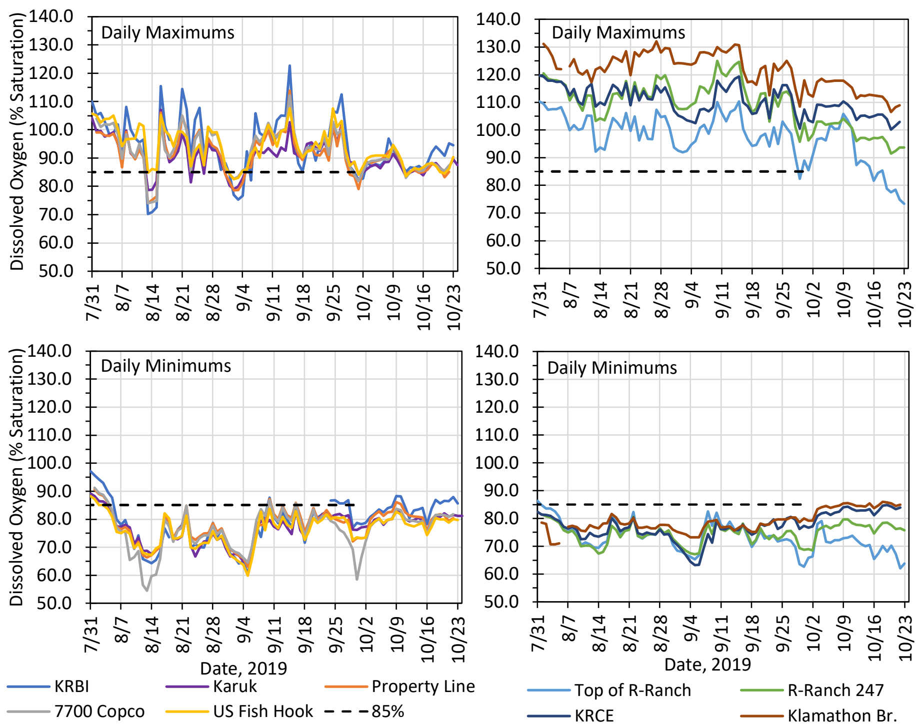


Figure 7. Daily minimum and maximum dissolved oxygen (percent saturation) data through the study reach downstream of Iron Gate Dam, and 85 percent saturation threshold (dashed line): July 31 through October 23, 2019.

Table 2. Iron Gate Reservoir barrier curtain deployment depths (m) in 2019.

Date	Depth (m)
August 6	3.0
August 12	6.1
August 16	3.0
September 4	1.5
September 13	3.0
November 1*	1.5

*The precise date the curtain was completely furled in 2019 is unclear, but it was after October 31 when Iron Gate Reservoir barrier curtain data collection stopped.

Detailed DO data by site, as well as associated water temperature data, at all monitoring sites downstream of Iron Gate Dam, are included as figures in Appendix B.

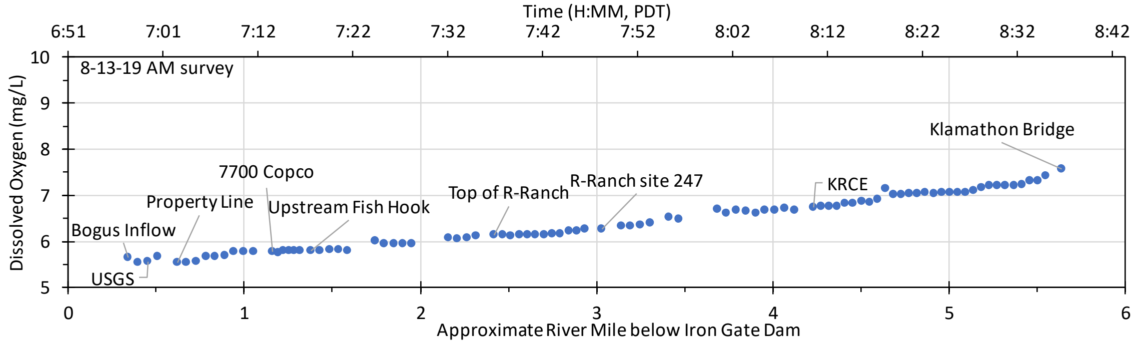
3.1.2. Longitudinal Surveys

Longitudinal surveys were conducted by boat twice per day on August 13, 2019 and on September 24, 2019, and included the collection of DO data (mg/L and percent saturation[5]) with a sonde logging at 1-min intervals while traveling at the approximate

[5] The 6600 data sonde collected sea level-corrected dissolved oxygen percent saturation data. Site-specific dissolved oxygen percent saturation data (local) were calculated and are presented throughout report.

speed of the river (logging approximately every 0.05 river mile). The instrument collected data from a depth of approximately 0.5 m, but was raised or removed from the water when passing through shallow stretches with visible rocks to prevent damage to the instrument. Data collected when the instrument was not in the water were removed from the final data analysis.

On August 13, 2019, DO concentrations approximately 0.3 river miles downstream of Iron Gate Dam were 5.6 mg/L (68 percent saturation) during both the morning and afternoon surveys (Figure 8 and Figure 9). Dissolved oxygen concentrations and percent saturation increased steadily in the downstream direction during both morning and afternoon surveys, with levels in the afternoon increasing at a greater rate. In the morning, DO concentrations reached 7.6 mg/L (90 percent saturation) at the Klamathon Bridge (Figure 8(a) and Figure 9(a)). In the afternoon, DO concentrations reached 9.1 mg/L (114 percent saturation) at the Klamathon Bridge (Figure 8(b) and Figure 9(b)). The increased rate of reaeration in the downstream direction during the afternoon survey can be attributed to photosynthesis, while the morning survey reaeration rates largely reflect mechanical reaeration. These values agree with data collected with continuous U-26 meters on August 13, 2019 (Figure 4 and Figure 5), which corresponded with the deepest Iron Gate Reservoir barrier curtain deployment depth of the season (Table) and reduced DO concentrations in dam releases. During this mid-August period with sub-saturation DO conditions downstream of Iron Gate Dam, levels reached 85 percent saturation about 5.2 river miles downstream Iron Gate Dam (between the KRCE and Klamathon Bridge sites) during the morning survey (Figure 9(a)) and about 2.2 miles downstream of Iron Gate Dam (between the Upstream Fish Hook site and Top of R-Ranch sites) during the afternoon survey (Figure 9(b)).



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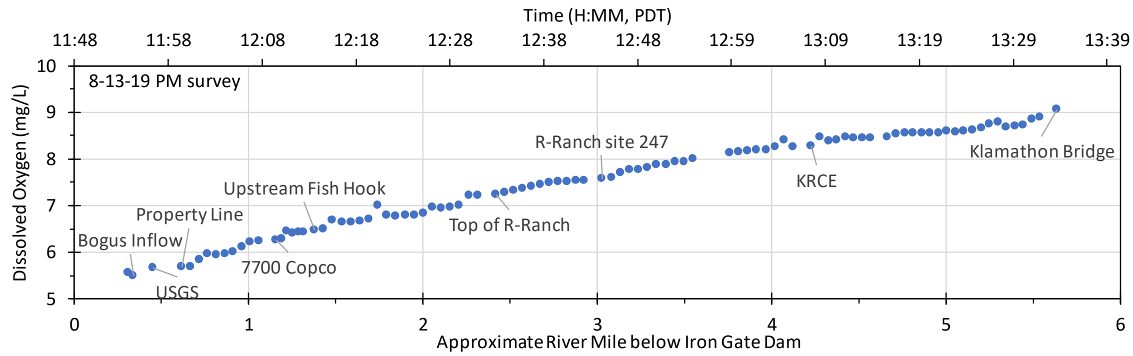

(b)

Figure 8. Dissolved oxygen (mg/L) collected during (a) morning and (b) afternoon longitudinal surveys: August 13, 2019.

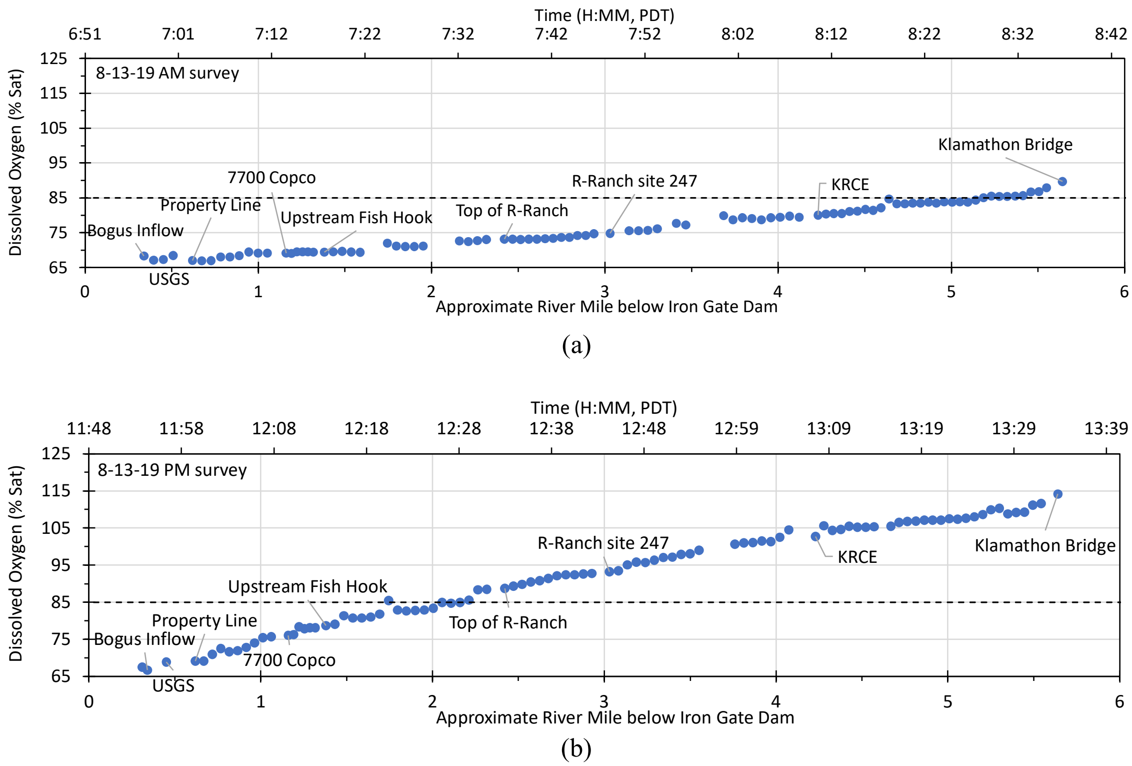

Figure 9. Dissolved oxygen (percent saturation) collected during (a) morning and (b) afternoon longitudinal surveys: August 13, 2019. Dashed line is 85 percent saturation.

On September 24, 2019, DO concentrations approximately 0.3 river miles downstream of Iron Gate Dam were 7.7 mg/L (88 percent saturation) during the morning survey and 7.8 mg/L (86 percent saturation) downstream of the dam during the afternoon survey (Figure 10 and Figure 11, respectively). Dissolved oxygen concentrations and percent saturation increased steadily in the downstream direction during both morning and afternoon surveys, with levels in the afternoon increasing at a greater rate. In the morning, DO concentrations reached 8.7 mg/L (99 percent saturation) at the Klamathon Bridge (Figure 10(a) and Figure 11(a)). In the afternoon, DO concentrations reached 10.0 mg/L (120 percent of saturation) at the Klamathon Bridge (Figure 10(b) and Figure 11(b)). As was observed during the August 13 survey, the increased rate of reaeration in the downstream direction during the afternoon survey can be attributed to photosynthesis, while the morning survey reaeration rates largely reflect mechanical reaeration. These values are in agreement with data collected by the deployed U-26 meters on September 24, 2019 (Figure 4 and Figure 5). The September 24, 2019 longitudinal surveys occurred when DO levels had begun to increase toward the end of the productive season (Figure 3) and corresponded with an Iron Gate Reservoir barrier curtain deployment of 3.0 m (Table). Dissolved oxygen was already above 85 percent saturation during the first measurement 0.3 river miles downstream of Iron Gate Dam near the Iron Gate Hatchery for both morning and afternoon surveys (Figure 11).

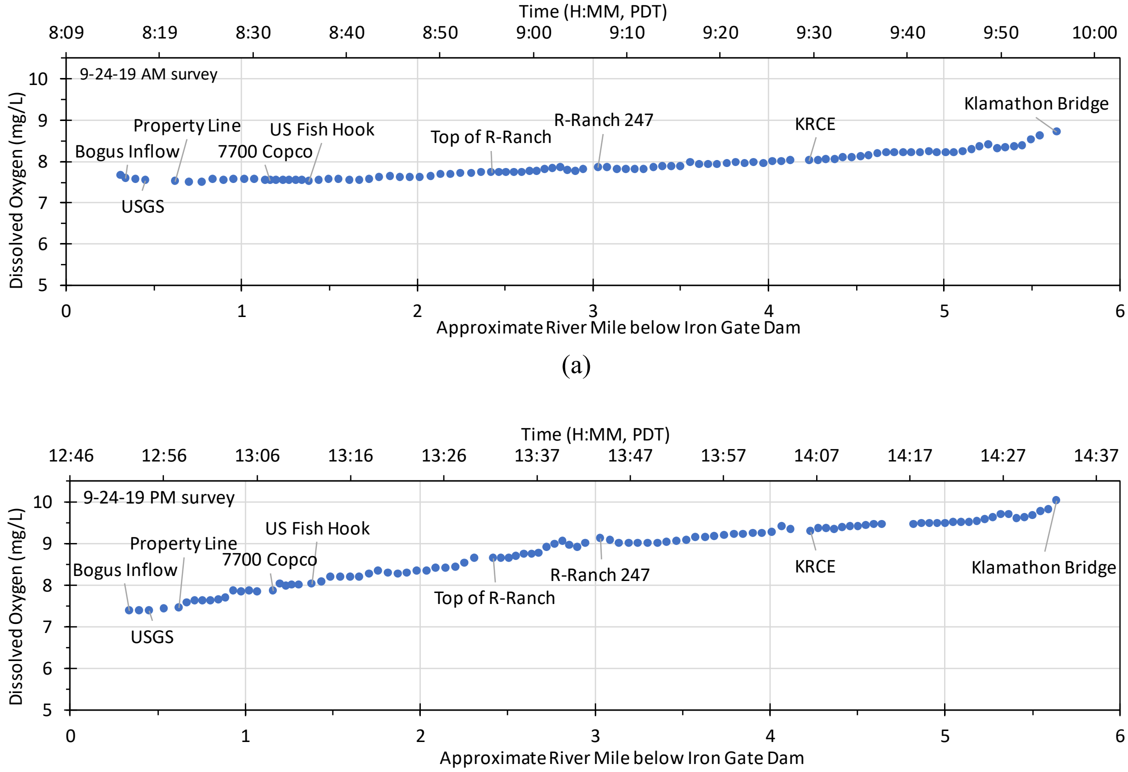

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Figure 10. Dissolved oxygen (mg/L) collected during (a) morning and (b) afternoon longitudinal surveys: September 24, 2019.

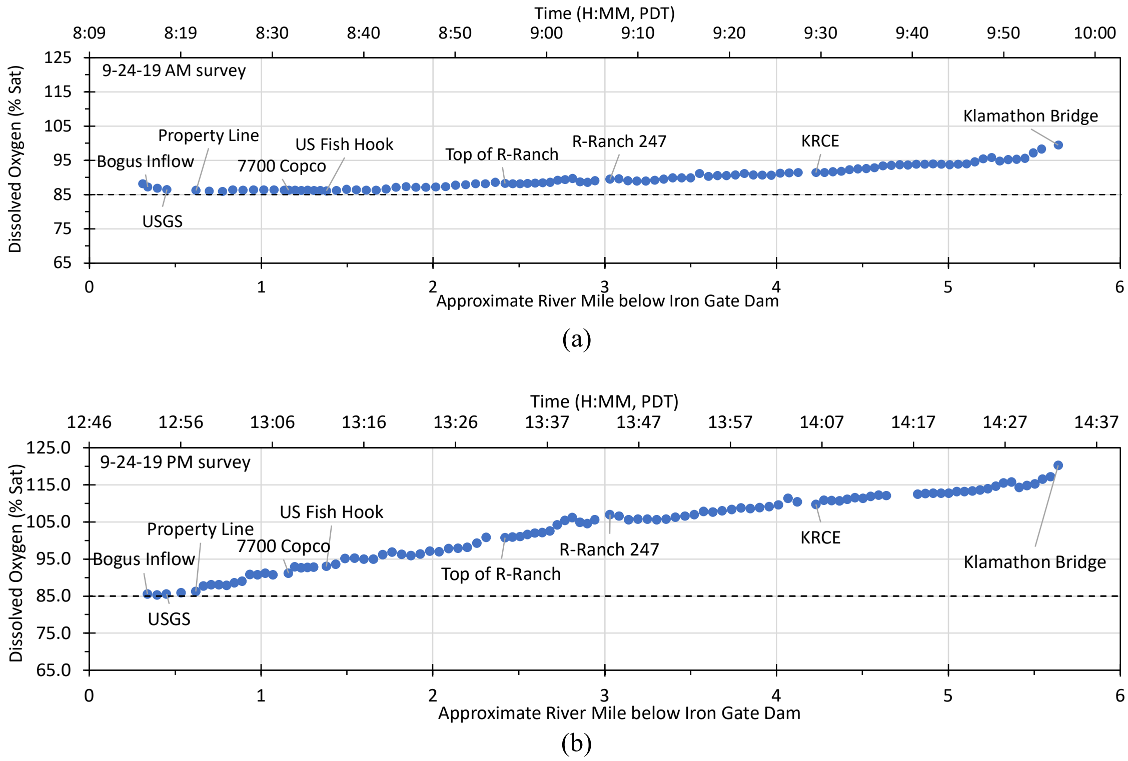
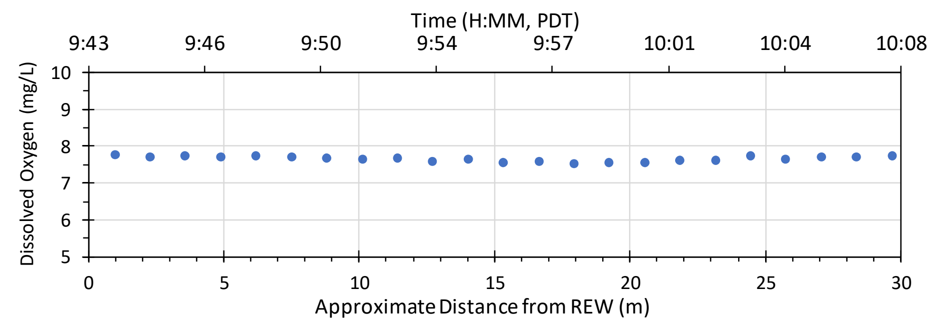


Figure 11. Dissolved oxygen (percent saturation) collected during (a) morning and (b) afternoon longitudinal surveys: September 24, 2019. Dashed line is 85 percent saturation.

3.1.3. Lateral Surveys

To assess potential variation laterally across the river, selected lateral surveys were completed at a cross-section that spanned the river at the KRCE suspension bridge. This survey was completed on August 13, 2019 (Figure 12) and on September 24, 2019 (Figure 13). Dissolved oxygen data collected within the cross-section varied by 0.2 mg/L (2 percent saturation) on August 13 and by 0.4 mg/L (5 percent saturation) on September 24 (Figure 12 and Figure 13, respectively). These results support the use of both fixed location continuous meter data and longitudinal survey data to represent the general trends in the river in the study reach.



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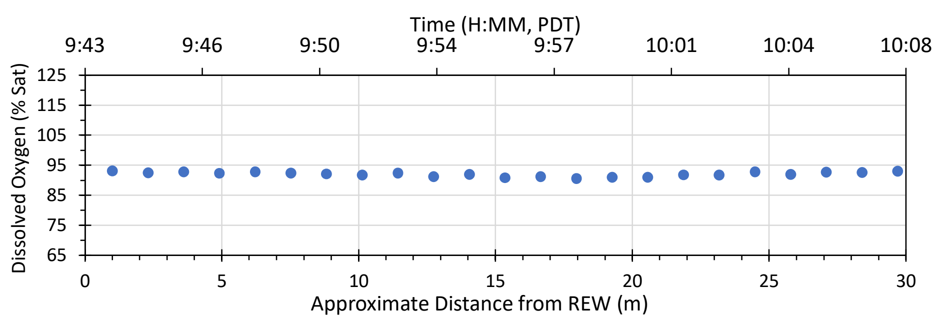

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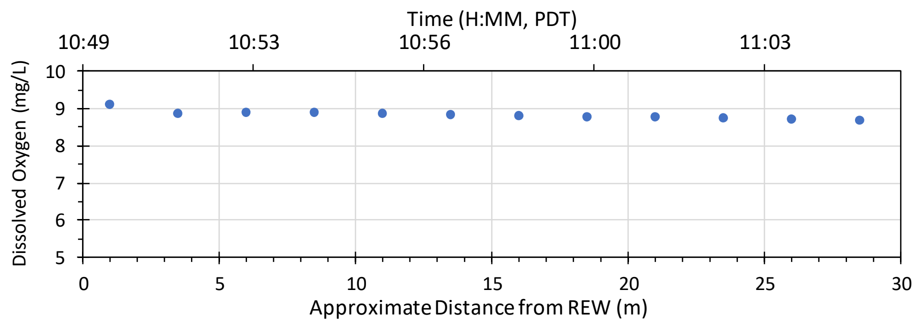
Figure 12. Dissolved oxygen lateral variability at a cross-section at the KRCE, with (a) mg/L and (b) percent saturation values: August 13, 2019. Cross-section spans 30 m with data collected every 1.3 m.



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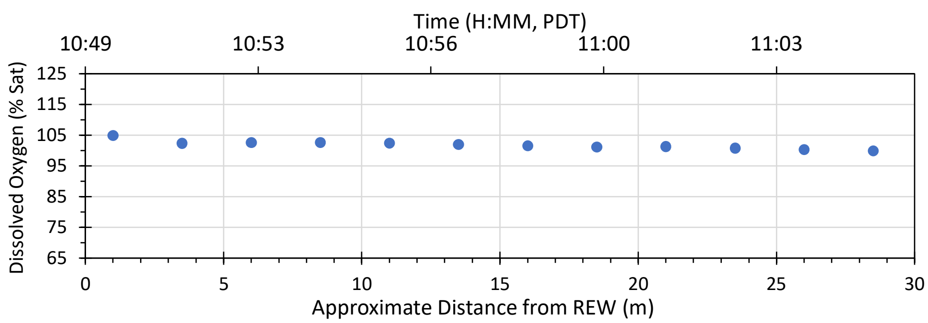

(b)

Figure 13. Dissolved oxygen lateral variability at a cross-section at the KRCE, with (a) mg/L and (b) percent saturation values: September 25, 2019. Cross-section spans 30 m with data collected every 2.5 m.

4. Mechanical reaeration downstream of Iron Gate Dam

Dissolved oxygen measurements collected early in the morning in the Klamath River downstream of Iron Gate Dam (Figure 8(a) and Figure 9(a)) increased at a lower rate in comparison to DO measurements collected in the afternoon (Figure 8(b) and Figure 9(b)). Morning DO concentrations are dominated by mechanical reaeration, while afternoon dissolved oxygen concentrations are dramatically affected by photosynthesis. To explore reaeration rates associated with mechanical reaeration, DO concentrations from morning longitudinal surveys were used in conjunction with empirical reaeration relationships to calculate mechanical reaeration rates downstream of Iron Gate Dam.

Reaeration rate coefficients (1/day and 1/mile) were calculated using empirical reaeration relationships for rivers described in the literature by Churchill et al. (1962), O'Conner-Dobbins (1958), and Owens et al. (1964) (equations 1-3, Table 3). Reaeration calculations employed Klamath River water velocities for the first 5 miles downstream of Iron Gate Dam at approximately 900 cfs (1.79 feet per second (ft/s) for August) and 1,000 cfs (1.83 ft/s for September) (Deas et al. 1999), and an average river depth of 3.00 feet (ft). Reaeration rate coefficients for the three empirical relationships (Table 3) were applied to initial and equilibrium (DO saturation) values in August and September (Table 4) and modeled data are compared to survey data (Figure 14 and Figure 15).

Churchill et al. (1962)

$$k = \frac{11.6u\hat{}0.969}{h^{1.673}} \qquad \text{(equation 1)}$$

where:
k = reaeration rate coefficient (1/day)
u = velocity (ft/s)
h = depth (ft)
Applicable to: moderate, deep, faster velocity streams (Bowie et al. 1985)

O'Conner-Dobbins (1958)

$$k = \frac{12.9u^{0.5}}{h^{1.5}} \qquad \text{(equation 2)}$$

where:
k = reaeration rate coefficient (1/day)
u = velocity (ft/s)
h = depth (ft)
Applicable to: moderate, deep, moderate velocity streams (Bowie et al. 1985)

Owens et al. (1964)

$$k = \frac{21.7u^{0.67}}{h^{1.85}} \qquad \text{(equation 3)}$$

where:
k = reaeration rate coefficient (1/day)
u = velocity (ft/s)
h = depth (ft)
Applicable to: shallower streams (Bowie et al. 1985)

Table 3. Dissolved oxygen calculated reaeration rate coefficients (k per day and k per mile) from reaeration relationships.

		k (1/day) [2]			k (1/mile) [2]		
Date-Time (PDT)	Approx. River Miles DS [1] Iron Gate Dam	Churchill et al. (1962)	O'Conner-Dobbins (1958)	Owens et al. (1964)	Churchill (1962)	O'Conner-Dobbins (1958)	Owens et al. (1964)
8-13-2019 7:02 to 8:38 AM	0.7 to 5.6	3.25	3.32	4.20	0.11	0.11	0.14
9-24-2019 8:21 to 9:58 AM	0.7 to 5.6	3.32	3.36	4.26	0.11	0.11	0.14

(1) DS is downstream
(2) All k reaeration rate coefficients are base e, and are referenced to 20°C

Table 4. Dissolved oxygen concentrations (mg/L) during longitudinal surveys

Date-Time (PDT)	Approx. River Miles DS[1] Iron Gate Dam	DO concentration (mg/L)		
		Initial[2]	Final[2]	Saturation[3],[4]
8-13-2019 7:02 to 8:38 AM	0.7 to 5.6	5.54	7.57	8.40
9-24-2019 8:21 to 9:58 AM	0.7 to 5.6	7.49	8.71	8.72

[1] DS is downstream
[2] Measured value
[3] Calculated value
[4] Calculated based on measured atmospheric pressure and water temperature

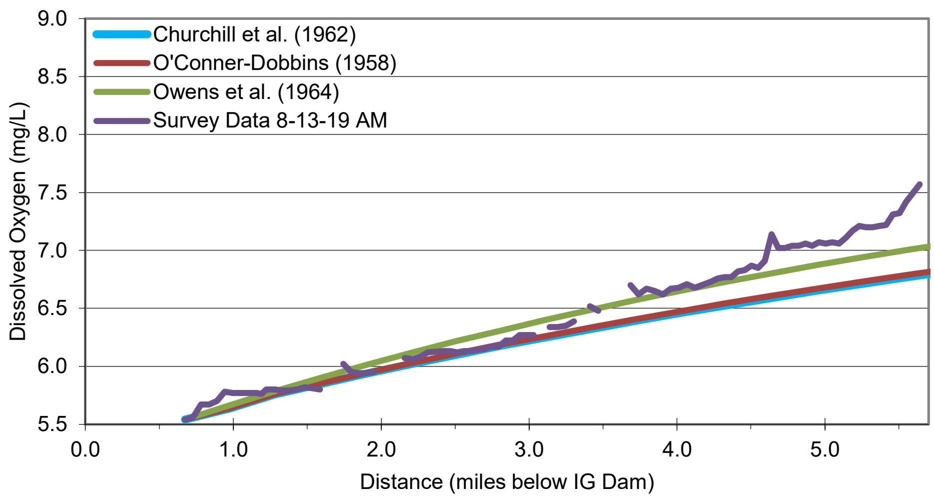

Figure 14. Measured and calculated dissolved oxygen reaeration by distance downstream Iron Gate Dam: August 14, 2019 7:02 to 8:38 AM.

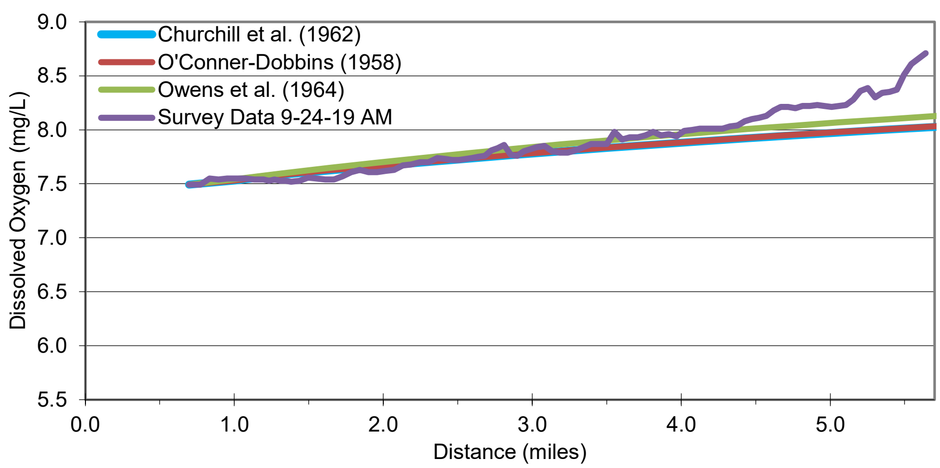

Figure 15. Measured and calculated dissolved oxygen reaeration by distance downstream Iron Gate Dam: September 24, 2019 8:21 to 9:58 AM.

This 5.6-mile reach of the Klamath River downstream of Iron Gate Dam was best represented with the Owens et al. (1964) relationship. Data modeled with this relationship were not greater than 0.57 mg/L DO, and no less than 0.12 mg/L DO, from measured data on August 13, 2019; and no greater than 0.60 mg/L DO, and no less than 0.11 mg/L

DO, from measured data on September 24, 2019. Average bias was 0.07 mg/L and 0.04 mg/L greater for DO concentration modeled with the Owens et al. (1964) relationship than for measured DO concentration for the August survey and the September survey, respectively. Other reaeration relationships examined [Churchill et al. (1962) and O'Conner-Dobbins (1958)] were similar, although Owens et al. (1964) provided the best fit to measured data and is recommended for future use if reaeration rates are desired. There is considerable photosynthesis and respiration associated with primary production in this reach and conditions can also vary longitudinally. At certain locations lateral distribution of aquatic vegetation would yield notable lateral differences in DO (Deas pers. comm.). Dissolved oxygen concentrations during lateral surveys did not vary considerably, largely because the cross-section was completed at a location that was relatively free of macrophytes and minimal attached algae, similar to U-26 meter sites. Near the end of each longitudinal survey DO conditions increased, deviating from the empirical relationship, possibly as a result of photosynthesis. Nonetheless, the analysis indicates that empirical relationships can be used in characterizing reaeration rates and DO conditions in this reach of the Klamath River.

5. Conclusions and Recommendations

Dissolved oxygen concentrations and percent saturation values downstream of Iron Gate Dam increase in the downstream direction. Sub-saturation DO conditions in Iron Gate Dam releases increased steadily with increasing distance from the dam; DO percent saturation was always above 85 percent at the Klamathon Bridge about 5.6 miles downstream of Iron Gate Dam. Longitudinal survey data closely mirrored continuous data and cross sections indicated relatively little variation in DO concentrations across the channel.

Mechanical reaeration plays a key role in increasing DO concentrations with increasing distance from Iron Gate Dam, while photosynthesis augments mechanical reaeration, especially later in the day. Mechanical reaeration rates were determined both graphically (field data) and compared with empirical [Churchill et al. (1962), O'Conner-Dobbins (1958), and Owens et al. (1964)] relationships. The Owens et al. (1964) empirical reaeration relationship matched relatively well with measured dissolved oxygen data in the river downstream of Iron Gate Dam.

5.1. Recommendations

Several recommendations were developed to guide future monitoring for the determination of DO recovery downstream of Iron Gate Dam:

- Additional longitudinal surveys are not necessary to determine DO recovery by the Klamathon Bridge site.

- The empirical relationship provided by Owens et al. (1964) provided the best fit to measured longitudinal survey data and as such, is recommended if future reaeration rates are desired.

- Although Onset U-26 DO meters contain a copper anti-fouling ring, they do not have a wiper and at times, biofouling can accumulate (see 2018 data presented in Appendix B). The 3-week maintenance interval followed during 2019 monitoring prevented the build-up of significant amounts of biofouling and is recommended for future monitoring with these devices.

- Data collected by Onset U-26 DO meters were similar at the Property Line and 7700 Copco (approximate river miles 0.6, and 1.2 below Iron Gate Dam, respectively). Additionally, the distance between 7700 Copco and Upstream Fish Hook sites is only 0.2 river miles, less than the distance between any other two adjacent sites. Therefore, we recommend removing the 7700 Copco site for future monitoring.

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Appendix A. Monitoring Plan

A.1. Continuous Dissolved Oxygen Monitoring

Field activities will include deploying and maintaining Onset® HOBO® U26 (hereafter U26) dissolved oxygen (DO) meters downstream of Iron Gate Dam. U26 deployment in July will be based on project team field monitoring experience, previous DO monitoring completed in the project reach, and on findings of the scoping trip. The scoping trip was completed on June 10, 2019, and included a float trip from Lakeview Road Bridge to the Klamathon Bridge. Project team members Demian Ebert (PacifiCorp) and Brooke Mejica, Jeff Laird, and Mike Deas (Watercourse) participated in the trip with the specific objectives of:

a. Identifying DO continuous monitoring locations in the Klamath River project area

b. Determining deployment methods and locations and means of attaching units to shoreline

c. Considering shoreline access and potential vegetation fouling issues

d. Assessing retrieval options for download and redeployment through the summer and into fall

A.1.1. Site Locations

Instrumentation will be installed at seven sites between the KRBI site and Klamathon Bridge. Site locations were chosen to be representative of flowing water condition in a longitudinal transect downstream of Iron Gate Dam (e.g., avoid backwater areas, areas with excessive aquatic vegetation, and install at reasonable depth and distance from the shoreline, install at relatively even intervals between KRBI and Montague Bridge with increased density in the upstream reach), and to provide access from the river right shoreline (except for Klamath River at PacifiCorp Property Line). Because the reach consists largely of a continuous series of runs and riffles, the reaeration coefficient[6] between the KRBI site and Klamathon Bridge is expected to be fairly consistent. Thus, having an evenly distributed spacing of monitoring sites is appropriate. Final site locations were determinized in cooperation with PacifiCorp.

Site locations include (Table A-1):

1. Klamath River at PacifiCorp Property Line, approximately 0.6 river miles downstream from Iron Gate Dam

2. Klamath River at 7700 Copco Road, approximately 1.2 river miles downstream from Iron Gate Dam

[6] Reaeration rate equals the reaeration coefficient multiplied by the DO deficit or surplus: $\Delta O = kt(O_s - O)$, where ΔO is oxygen concentration over time period t, k is reaeration coefficient, O_s is DO saturation concentration.

3. Klamath River upstream Fish Hook Restaurant at Blue Heron RV park, approximately 1.4 river miles downstream from Iron Gate Dam

4. Klamath River at Top of R-Ranch, approximately 2.4 river miles downstream from Iron Gate Dam

5. Klamath River at R-Ranch campsite 247, approximately 3.0 river miles downstream from Iron Gate Dam

6. Klamath River Country Estates Campground at Suspension Bridge, approximately 4.2 river miles downstream from Iron Gate Dam

7. Montague (Klamathon) Bridge, approximately 5.6 river miles downstream from Iron Gate Dam

In addition to these seven sites, DO data collected for baseline KHSA monitoring at Klamath River downstream of Iron Gate Dam, approximately 0.3 river miles downstream from Iron Gate Dam (RM 189.73), will be reviewed and included in the DO report. Data at the Karuk site downstream of Iron Gate Dam will be included, if available. A map illustrating the locations and spacing of all nine final 2019 data collection sites are provided (Figure A-1 and Figure A-2).

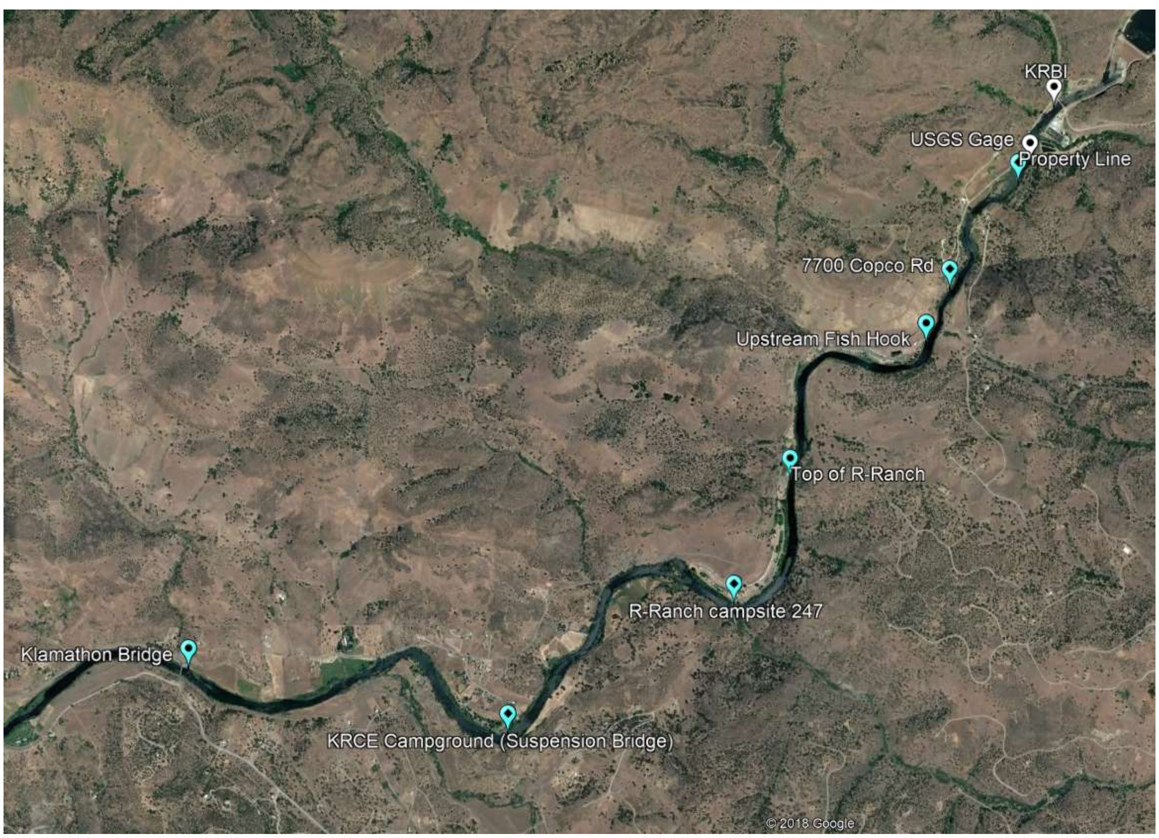


Figure A-1. Map of 2019 monitoring locations with U26 logger locations (blue) and other devices (white).

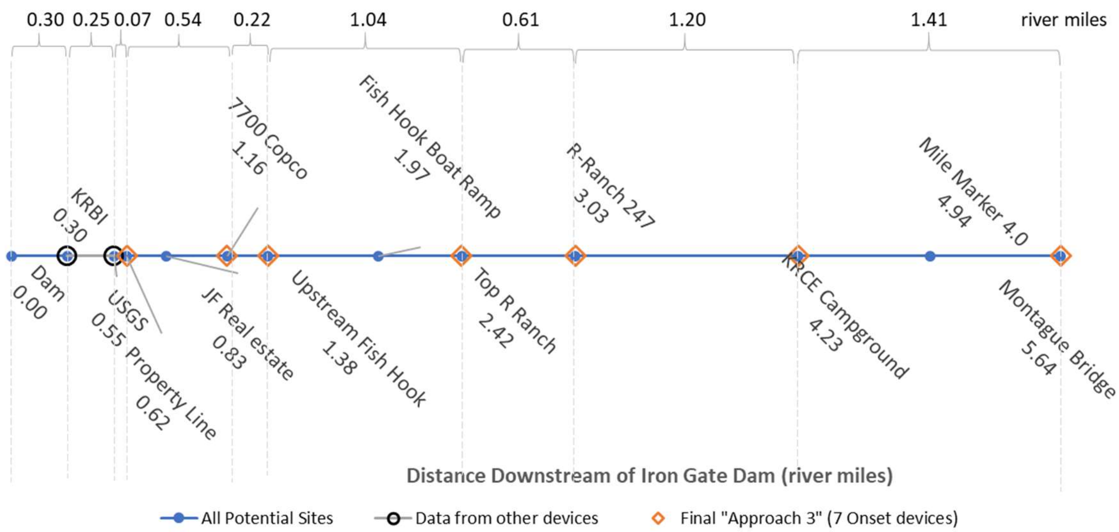


Figure A-2. Spacing of potential monitoring sites (blue circle), other devices (black circle), and all final U26 2019 monitoring sites (orange diamond).

A.1.2. Site Access Protocols

Access to river for installation and maintenance was acquired in cooperation with the PacifiCorp. Three sites require contact prior to each site visit. Site name, distance from Iron Gate Dam, latitude and longitude, and descriptions are included here (Table A-1).

Table A-1. 2019 dissolved oxygen continuous monitoring sites, locations (x, y), and site descriptions.

Site Name	Approximate distance downstream Iron Gate Dam (mi)	Latitude	Longitude	Site Description
Property Line	0.6	41.926700	-122.444800	First accessible site upstream from PacifiCorp property line, river left
7700 Copco Rd	1.2	41.920655	-122.450030	At downstream end of 7700 Copco, at property line, river right
US Fish Hook	1.4	41.917580	-122.451830	At upstream end of the Blue Heron RV Park property, river right
Top of R-Ranch	2.4	41.909927	-122.462209	At upstream end of the R-Ranch property, near the lodge, river right
R-Ranch site 247	3.0	41.902800	-122.466500	Adjacent to campsite 247, also accessible from R-Ranch beach near fish cleaning station, river right
KRCE Campground	4.2	41.895442	-122.483738	Directly upstream of the KRCE Campground suspension bridge, river right
Montague Bridge	5.6	41.899136	-122.508103	Upstream of the Montague (Klamathon) bridge, river right.

A.1.3. Parameters and Frequency

Instrumentation will collect DO (mg/L) and water temperature data at 15-minute intervals with the U26 data logger (Table A-2). Dissolved oxygen (site-specific percent saturation[7], mg/L) and water temperature data will be collected with a YSI Professional Plus periodically for field calibrations and spot measurements to adjust for bio-fouling and confirm the flowing condition of the river (Table A-3). Dissolved oxygen concentrations (mg/L) will be converted to site-specific DO percent saturation with Onset's Dissolved Oxygen Assistant software in the office after data has been downloaded (Section A.1.14).

Table A-2. Onset® HOBO® U26 parameters and specifications

Parameter	Sensor Type	Accuracy	Resolution
Dissolved Oxygen (mg/L)	Optical	±0.2 mg/L up to 8 mg/L; ±0.5 mg/L from 8 to 20 mg/L	0.02 mg/L
Temperature	-	±0.2°C (0.36°F)	0.02°C (0.04°F)

Table A-3. YSI Professional Plus parameters and specifications

Parameter	Sensor Type	Accuracy	Resolution
Dissolved Oxygen (% saturation)	Polarographic	±2% of reading or 2% air saturation, whichever is greater	0.1%
Dissolved Oxygen (mg/L)	Polarographic	±0.2 mg/L or ±2% of reading, whichever is greater from 0 to 20 mg/L	0.01 mg/L
Temperature	-	±0.2°C (0.36°F)	0.1°C (0.18°F)

A.1.4. Equipment Maintenance

Maintenance will include cleaning to remove bio-fouling at a minimum of 3-week intervals and calibration and data downloads at a minimum of 6-week intervals. Spot measurements with a secondary instrument will occur during maintenance visits. The secondary instrument will be calibrated prior to each use.

A.1.5. Field Checklist

The field checklist and field procedures for DO probe retrieval/deployment cleaning, download, and calibration are outlined below.

- Heavy chain in lengths to deploy each instrument into flowing water (sufficient for lowest flows of season)
- Bolt-cutters and extra fasteners to attach chain
- Extra chain for extensions
- Locks and keys to secure end of chain on shore (to tree)
- Onset® HOBO® U26 user manual
- 2019 Klamath River below Iron Gate DO Monitoring Plan
- Onset® HOBO® U26 devices

[7] Calculated with true barometric pressure; therefore, the fully saturated value is 100 percent, regardless of pressure values.

- Laptop computer with HOBOware Pro® Version 3.7.16 software and Dissolved Oxygen Assistant
- HOBO Waterproof Shuttle (U-DTW-1), coupler (COUPLER2-C), and USB cable
- Sodium sulfite solution [5 x 500 mL bottles, 5% w/v]
- 7.6 cm (3 inch) tall 100 mL beaker
- Deionized or distilled water (DI) (at least 8 liters)
- Squirt bottle (to clean sensor tip)
- White vinegar
- Alconox®
- Rag
- Large Brush to clean pipe casing
- Medium/small plastic brush or nylon dish scrubber to clean U26 body
- Soft toothbrush or soft cloth to clean U26 sensor cap
- YSI handheld Pro ODO, calibrated on site (for spot measurements and barometric pressure readings during U26 calibrations)
- Field sheets, Calibration sheets, pens
- Waders and belt, wading boots, hip boots, life vest, and second person for safety

A.1.6. Order of Operations

Instrumentation and c-channel housing will be cleaned prior to initial deployment (if necessary) and cleaned at a minimum of 3-week intervals (Section A.1.8). Instrumentation will be calibrated prior to the initial deployment and again at a minimum of 6-week intervals (Section A.1.9). Field calibration data will be collected at the beginning of each U26 deployment and prior to removing the U26 for downloads and maintenance, and an additional spot measurement will be collected at the end of a deployment if the U26 is no longer within the flowing condition of the river (Section A.1.12).

A.1.7. DO Sensor Cap replacement

Prior to initial cleaning, calibration, and deployment, the sensor caps will be replaced as directed in the U26 user manual.

A.1.8. Cleaning

Instrumentation and pipe casing will be cleaned at a minimum of 3-week intervals. Cleaning will include removing instrument from pipe casing, brushing out the inside and outside of the pipe casing, and cleaning the U26.

Prior to removing or cleaning U26 from the water:

1. Collect field calibration information with the U26 and collect a spot measurement within the flowing condition, if necessary (Section A.1.12).

To clean the U26 sensor cap:

1. Remove the protective guard or anti-fouling guard, but leave the sensor cap on the sensor.

2. Rinse the logger with clean water from a squirt bottle or spray bottle.
3. Gently wipe the cap with a soft-bristled brush (such as a toothbrush) or soft cloth if biofouling is present. Use Alconox® to remove grease, if present.
4. If extensive debris or mineral build-up is present, soak the cap end in vinegar for 15 minutes, then soak it in DI water for another 15 minutes.

To clean the U26 sensor body:

1. Make sure the sensor cap is installed on the logger.
2. Gently scrub the logger body with a plastic bristle brush or nylon dish scrubber. Use Alconox® to remove grease, if present.
3. Soak in vinegar to remove mineral deposits.
4. Rinse the logger with DI water.

A.1.9. Calibration and Data Downloads

Instrumentation will be calibrated prior to the initial deployment and downloaded and calibrated at a minimum of 6-week intervals. All calibrations will include at least a 1-point calibration (to 100% saturation). A 2-point calibration (to 0% saturation and 100% saturation) will occur during the initial instrument deployment and upon instrument retrieval at the end of the season). A 2-point calibration may be added mid-season if review of preliminary data indicates it is necessary.

A.1.9.1. Data Downloads

After the initial calibration and deployment, data will be downloaded from U26 instruments prior to each calibration (minimum of 6-week intervals).

2. Collect field calibration data and spot measurement, if applicable, with YSI professional plus before removing U26 from its deployment location (Section A.1.12).
3. Remove U26 from the water and clean instrument and casing (Section A.1.8).
4. Connect the U26 to the computer using a HOBO Waterproof Shuttle (U-DTW-1), coupler (COUPLER2-C), and USB cable. With the logger connected to the computer, open HOBOware.
5. Read out the data from the logger by navigating to “File”, then “Readout”.
6. Review data, then export data into CSV format.
7. Calibrate (Section A.1.9.2), re-launch (A.1.10), re-deploy logger (Section A.1.11), and collect field calibration data (Section A.1.12).

A.1.9.2. Calibration

Two-point calibrations will be performed by first placing the logger in water-saturated air (100% saturation) and then placing the logger in sodium sulfite solution (0% saturation), as directed in the Onset® HOBO® U26 user manual. (Note: The 0% saturation calibration is recommended if the logger will be deployed in water with DO levels of 4 mg/L or less.) The two-point calibration will only be used before initial deployment and following logger retrieval at the end of the season; one-point calibration will be used during the field season.

1. The sodium sulfite solution should be left out long enough for temperature to stabilize in the environment that the calibration is performed.

2. If the logger was deployed previously, make sure the sensor is clean and dry (see Section A.1.8 for more details).

3. Connect the logger to the computer if not already connected, as described in Section A.1.10.

4. From the Device menu, click “Lab Calibration”.

5. Step 1: 100% Saturation

    a. In “Step 1: 100% Saturation” in the Lab Calibration window, enter the barometric pressure for your current location. If the barometric pressure reading has been adjusted for sea level (such as a reading taken from the National Weather Service weather station), select the “If using sea level barometric pressure, enter elevation” checkbox and enter your elevation in either meters or feet.

    b. Make sure the logger either has the protective guard or the anti-fouling guard installed (whichever guard you plan to use in the deployment) so that the sensor is covered.

    c. Wet the small sponge with fresh water. Squeeze out any excess water.

    d. Place the sponge in the end of the calibration boot.

    e. Insert the logger in the calibration boot so that there is approximately a 1 cm (0.5 inch) overlap between the end of the boot and the body of the logger. This will ensure there is enough space between the end of the logger and the sponge (the logger should not be pressed up tightly against the sponge).

    f. Wait for approximately 15 minutes until the logger reaches temperature equilibrium (and less than 30 minutes so the logger does not go to sleep).

    g. Click the “Get DO value from the logger” button to display the 100% saturation results. You can click this button as often as needed. The results are updated each time you click the button. To check for equilibrium, click the “Get DO value from the logger” button several times in a row to check the current “DO Conc from logger at 100% Saturation” value. If the value remains the same or varies very little with each button click, then temperature equilibrium has likely been reached.

h. When you are satisfied with the results displaying in the “Step 1: 100% Saturation” tab, click the Next button to proceed to “Step 2: 0% Saturation.”

6. Step 2: 0% Saturation

   a. Make sure the logger either has the protective guard or the anti-fouling guard installed (whichever guard you plan to use in the deployment) so that the sensor is covered.

   b. Rinse the sensor tip well with sodium sulfite solution and then pour the sodium sulfite solution into the 7.6 cm (3 inch) beaker so that it is about two-thirds full.

   c. Place the sensor end of the logger into the solution so that the entire protective guard or anti-fouling guard and at least 2.5 cm (1 inch) of the logger body are submerged in the beaker. Allow it to rest on the bottom of the beaker.

   d. Wait for approximately 15 minutes until the logger reaches temperature equilibrium (and less than 30 minutes so the logger does not go to sleep).

   e. Click the “Get DO value from the logger” button to display the 0% saturation results. As with the 100% calibration, you can click this button as often as needed. The results are automatically updated each time you click the button. If the value remains the same or varies very little with each button click, then temperature equilibrium has likely been reached.

   f. When you are satisfied with the results displaying in the “Step 2: 0% Saturation” tab, click the Next button to proceed to “Step 3: Finish.”

7. Step 3: Finish

   a. The results from the 100% and 0% steps are displayed as well as the overall calibration results and the new gain and offset adjustment values. If you are satisfied with the results, write these down in the calibration sheet and click the “Send Calibration to Logger” button. The logger will then be calibrated based on the new values. (Note: these values will not take effect until the logger is launched. If you do not want to save these values, click Close to cancel the calibration and revert back to the last saved logger values. Or, click “Reset to Factory Defaults” to return to the original values.

b. Remove the logger from the solution and thoroughly rinse it with fresh water to remove any excess sodium sulfite.

8. Proceed to Section A.1.10 to launch the logger.

A.1.10. Launching

Before deploying, instrumentation will be cleaned (Section A.1.8) and calibrated (Section A.1.9), as needed to comply with the Order of Operations (Section A.1.6). To launch and deploy the U26 logger:

1. Connect the U26 to a field laptop using a HOBO Waterproof Shuttle (U-DTW-1), coupler (COUPLER2-C), and USB cable. Make sure to remove the calibration boot and screw on the protective sensor guard or anti-fouling guard.

2. Unscrew the pointed cap on the communications end of the logger.

3. Attach the coupler to the base station or shuttle.

4. Insert the logger into the coupler, aligning the bump/arrow on the coupler with the notches on the logger. Be sure that it is properly seated in the coupler. If the logger has never been connected to the computer before, it may take a few seconds for the new hardware to be detected by the computer. (Note: If you are using the HOBO Waterproof Shuttle as a base station with a computer, briefly press the coupler lever to put the shuttle into base station mode. A green LED on the shuttle or base station indicates good communication.)

5. With the logger connected to the computer, open HOBOware. From the Device menu, select Launch.

6. Select both the DO and Temperature channels to log. (Note: HOBOware provides the option of recording the current battery voltage at each logging interval, which is disabled by default. Recording battery life at each logging interval takes up memory and therefore reduces logging duration. It is recommended that you only record battery voltage for diagnostic purposes. Even with the channel disabled, a bad battery event will still be recorded.) Record remaining battery life and memory in field sheet.

7. Select 15-minutes for the logging interval.

8. Choose when to start logging and click the Start button. Record in field sheet.

9. Remove the logger from the coupler and screw the communications cap back on the logger.

10. Check that the sensor is logging (light blinks once every 8 seconds until logging begins; light blinks once every 4 seconds when logging begins).

A.1.11. Deployment

Dissolved oxygen instrumentation will be protected by fastening the logger into the top inside of a PVC pipe (inside diameter 4.0 inches, outside diameter 4.5 inches) with a stainless-steel bolt and zip-ties that will allow water to flow through and past the sensor tip and minimize interaction with the river bottom (Figure A-3). The PVC pipe will be bolted onto a c-channel to weight and reduce movement within the river channel (Figure A-4 and Figure A-5). The PVC pipe and the c-channel will be painted with a dark color paint to minimize biofouling, prevent oxygen reduction from oxidation of the metal, and minimize corrosion of the metal.

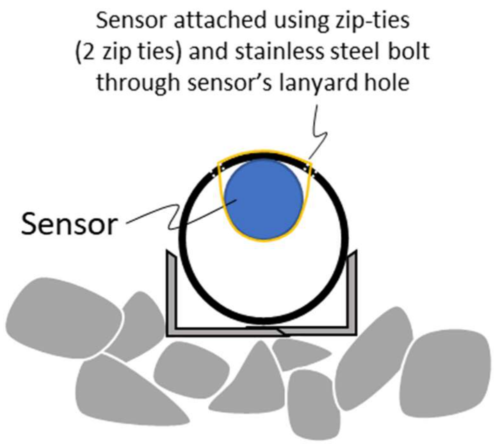


Figure A-3. Example of PVC pipe strapped onto c-channel and lead weight, side view and cross-section view.

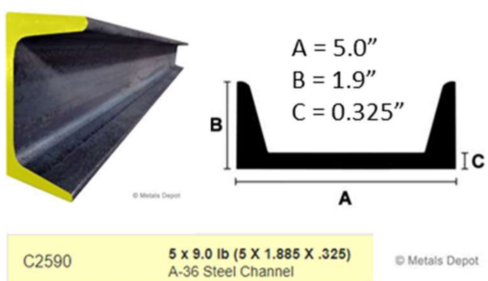


Figure A-4. C-channel picture and cross-section with dimensions.

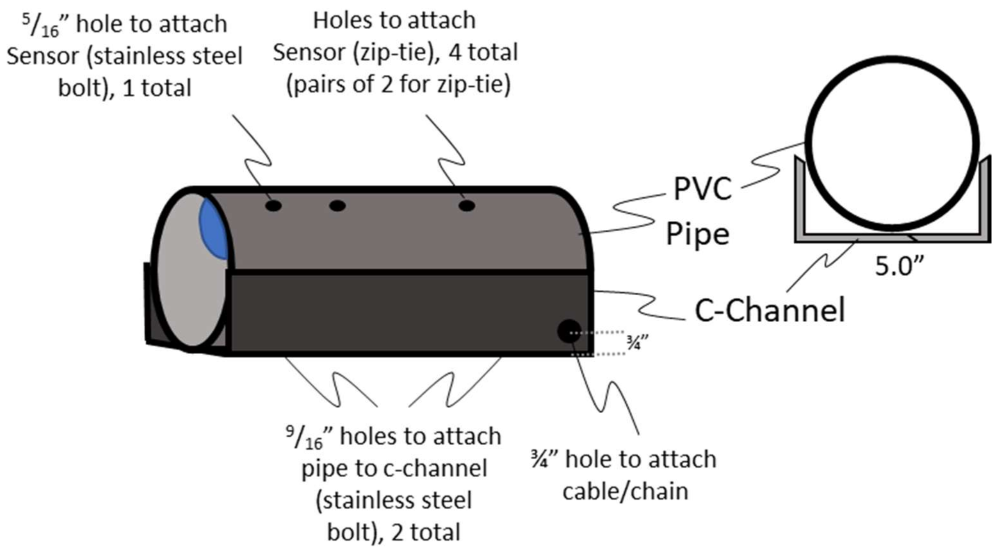


Figure A-5. Example of PVC pipe bolted onto c-channel, side view and cross-section view.

Sites will be accessed from the river-right shoreline (except Klamath River at PacifiCorp Property Line, which is accessed through the Iron Gate Fish Hatchery) (Section A.1.2). Heavy chain and a lock will be used to secure the pipe casing to a tree or other permanent shoreline structure. A photograph will document river conditions during each deployment and retrieval. The location of instrumentation within the channel will be documented on deployment and retrieval photographs.

After data download, cleaning, and/or calibration are complete, instrumentation will be deployed:

1. Strap the logger to the pipe casing with two zip ties.
2. Thread the stainless-steel bolt through the 5/16" bolt hole in the PVC pipe and through the 5/16" lanyard hole on the instrument. Fasten with a locking nut.
3. Fasten the loose end of the chain to a fixed location on the shoreline and lock it.
4. Fasten the other end of the chain to the ¾" hole on the c-channel.
5. Place the logger with housing out into the desired location within a flowing portion of the river, taking care to avoid backwater areas and areas with extensive macrophytes or periphyton.
6. Move the logger around slightly to eliminate any bubbles that may have formed.
7. Take a photo and complete field sheet to document deployment location, time, time zone, and river conditions.

8. Collect field calibration data with the YSI Professional Plus (Section A.1.12).

A.1.12. Field Calibration and Spot Measurements

A YSI Professional Plus meter will be used to collect field calibration data (i.e. DO and temperature) at the beginning of each U26 deployment and prior to removing the U26 for downloads and maintenance. These data will be collected as close to the Onset® HOBO® U26 as possible. If the U26 is no longer within the flowing condition of the river by the end of the deployment (e.g., from reduced flows or macrophyte growth), an additional spot measurement will be collected from the flowing section of the river to better characterize conditions and assess data. If it is suspected that fouling has affected data, field calibration data will be entered into the HOBOware Dissolved Oxygen Assistant to compensate for any measurement drift due to fouling.

To collect field calibration data:

1. The U26 logger must be logging.

2. Make sure the YSI Professional Plus meter is calibrated and allow time for the meter probe to stabilize (this will occur when three measurements taken in a row are within ±0.5 mg/L).

3. Take a DO measurement of the water where the logger is currently deployed using the YSI Professional Plus meter.

4. Record the reading, date, and time of the measurement in a field notebook.

5. Use the Dissolved Oxygen Assistant and barometric pressure data from the meteorological station on Iron Gate Dam (adjusted to site-specific barometric pressure[8]) to adjust data from the logger and compensate for any measurement drift due to instrument fouling. This may be done at the office.

If the U26 is no longer within the flowing condition of the river by the end of the deployment (e.g., from reduced flows or macrophyte growth), then:

1. Collect a reading next to the logger housing.

2. Collect an additional reading from a flowing section of the river at a depth of approximately 0.5 m.

Field calibration data and spot measurements, when appropriate, will allow interpretation of potential DO crashes in the Onset® HOBO® U26 data, such as those experienced in historic data, which may not be representative of flowing river conditions (e.g., backwater conditions; biofouling of sensor; macrophyte, sediment, or organic matter entrainment within casing).

[8] Site-specific barometric pressure is the true barometric pressure reading that is not corrected to sea level.

A.1.13. Retrieval

After field calibration and spot measurements (Section A.1.12), retrieve the U26 for cleaning, data download, and/or calibration. If flow conditions allow, wade out and retrieve. If flow conditions do not allow wading to the U26 location, carefully pull on the deployment chain to retrieve equipment. Remove large macrophytes or other debris from deployment chain. Follow with cleaning (Section A.1.8), data download (Section A.1.9.1), and/or calibration (Section A.1.9.2), depending on field schedule and instrumentation needs.

A.1.14. Percent Saturation Calculations

Site-specific percent saturation will be calculated with Onset's Dissolved Oxygen Assistant software using U26 concentration data (mg/L) corrected for fouling (Section A.1.12), 15-minute water temperatures from U-26 DO meters, 15-minute barometric pressure data from the meteorological station on Iron Gate Dam (adjusted to site-specific barometric pressure), and specific conductance from the Klamath River Below Iron Gate (KRBI) sonde averaged over the period that U-26 DO meters are deployed.

A.2. Longitudinal Dissolved Oxygen Monitoring

Continuous DO monitoring will be complimented by two longitudinal monitoring events between Lakeview Road Bridge and Klamathon Bridge. These surveys will include longitudinal profiles collected during the early morning and again at midday to capture diel variation in DO (for a total of four longitudinal surveys). Lateral variability across the river will be measured by collecting data across the river channel at one site. During these monitoring efforts, data will be collected at an increased interval (spatially and temporally) compared to continuous monitors.

A.2.1. Site Locations

Data will be collected for at least 16 locations spread across approximately equal intervals from the Klamath River below Iron Gate (RM 189.73) site to the Klamathon Bridge (RM 184.39). Lateral variability will be collected from the suspension bridge at Klamath River Country Estates Campground, 4.23 miles downstream Iron Gate Dam (RM 185.80).

A.2.2. Parameters and Frequency

Data collected during longitudinal profiles and lateral cross-section will include DO (% saturation and mg/L), water temperature (°C), measurement depth, and location (latitude, longitude). Location information will be collected via a handheld GPS (Garmin inReach). Dissolved oxygen and water temperature data were collected with a YSI Professional Plus meter or a YSI 6600 data sonde (Table A-4 and Table A-5).

Table A-4. YSI Professional Plus parameters and specifications

Parameter	Sensor Type	Accuracy	Resolution
Dissolved Oxygen (% saturation)	Polarographic	±2% of reading or 2% air saturation, whichever is greater	0.1%
Dissolved Oxygen	Polarographic	±0.2 mg/L or ±2% of reading, whichever is greater from 0 to 20 mg/L	0.01 mg/L
Temperature	-	+0.2°C (0.36°F)	0.1°C (0.18°F)

Table A-5. YSI 6600 data sonde specifications

Parameter	Sensor Type	Accuracy	Resolution
Dissolved Oxygen (% saturation)	Optical	±2% of reading or 2% air saturation, whichever is greater	0.1%
Dissolved Oxygen (mg/L)	Optical	±0.1 mg/L or ±1% of reading, whichever is greater from 0 to 20 mg/L	0.01 mg/L
Temperature	-	±0.15°C (0.36°F)	0.01°C (0.018°F)

A.3. Schedule

A scoping survey occurred on June 18, 2019. Installation and maintenance of U26 continuous DO monitors will span late-July through mid-October (Table A-6). Longitudinal profiles will be collected in August and September, in response to DO conditions in the reservoir and Iron Gate Barrier curtain depths (Table A-6).

Table A-6. Field schedule for dissolved oxygen continuous monitoring, scoping trip, and longitudinal surveys.

Task	Monitoring Subtask	2019				
		Jun	Jul	Aug	Sept	Oct
8a	Scoping Boat Trip	■				
	Continuous DO Monitoring		■	■	■	■
	Longitudinal Surveys			■	■	

U26 devices will be cleaned at 3-week intervals. Data downloads and calibrations will occur at no less than 6-week intervals. During the first site visit after initial deployment, data will be downloaded and reviewed. Calibration will occur if instrument drift is suspected. Otherwise, calibration will occur 6-weeks after initial deployment. Continuous dissolved oxygen devices will be retrieved in late-October.

A.4. References

Onset® Computer Corporation. (n.d). HOBO® Dissolved Oxygen Logger (U26-001) Manual, version 15603-J Man-U26x. Retrieved from: https://www.onsetcomp.com/files/manual_pdfs/15603-J%20MAN-U26x.pdf (April 2019)

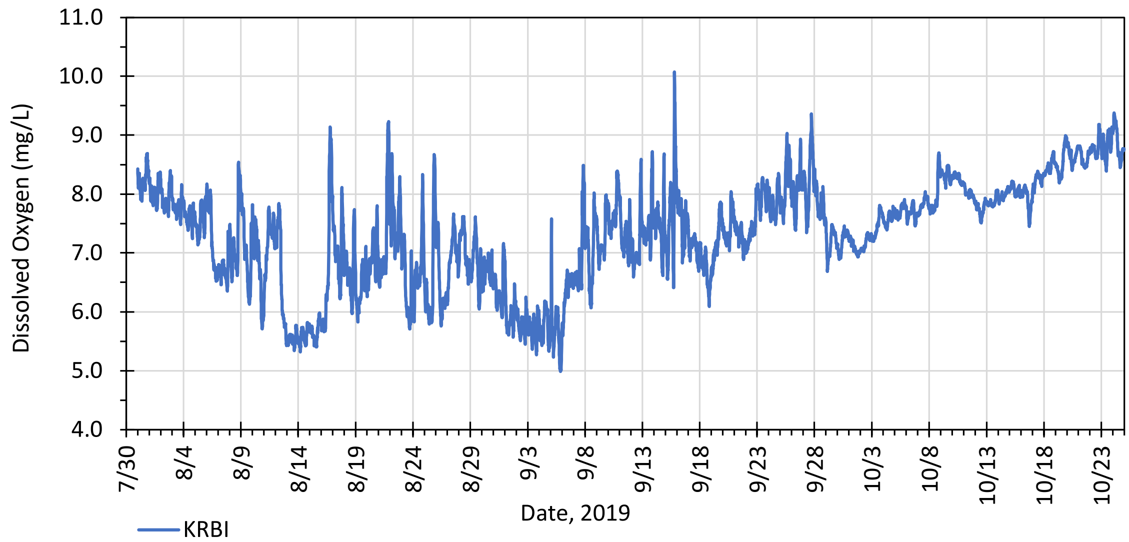
Appendix B. Additional Data

Appendix B includes dissolved oxygen (DO) and water temperature monitoring data collected in 2019 downstream of Iron Gate Dam. The data are displayed graphically by site and in greater detail than the report figures. Monitoring data from 2019 are also provided in spreadsheet format. Dissolved oxygen monitoring data collected by PacifiCorp in 2017 and 2018, which were invaluable for developing 2019 methodology, are also displayed graphically.

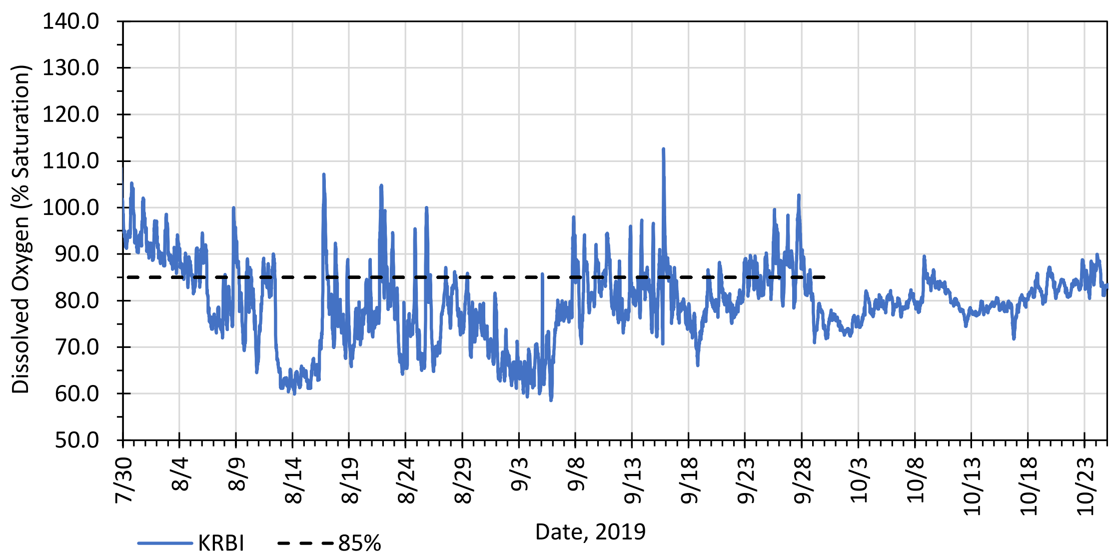
B.1. 2019 Continuous Dissolved Oxygen Data Downstream of Iron Gate Dam

Dissolved oxygen data (mg/L and percent saturation[9]) downstream of Iron Gate Dam are displayed by site (Figure B-1 through Figure B-9).

[9] DO percent saturation values are site-specific, and calculated with site-specific barometric pressure and specific conductance.

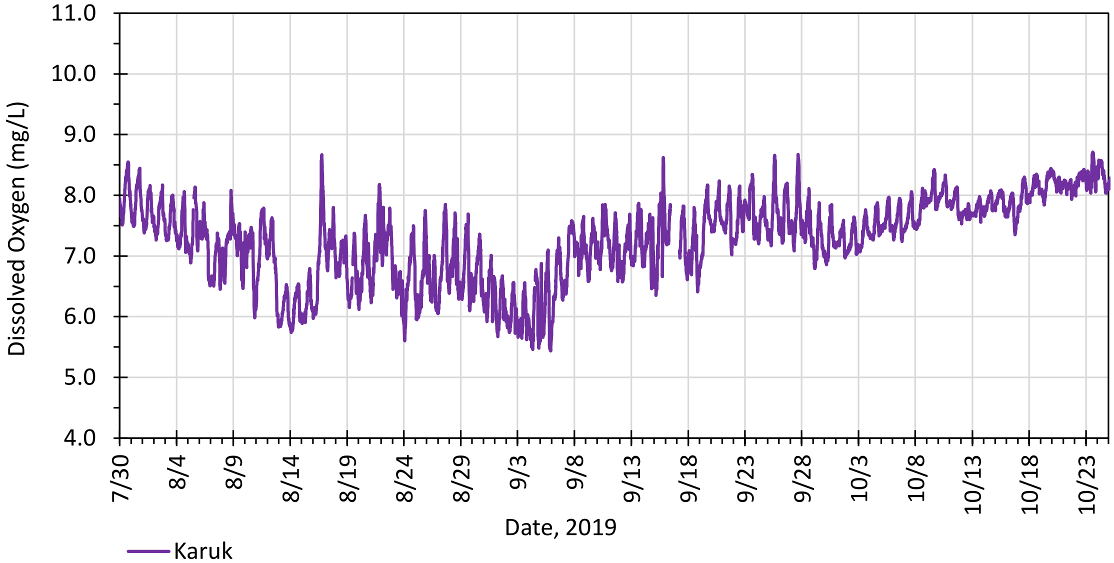


(a)

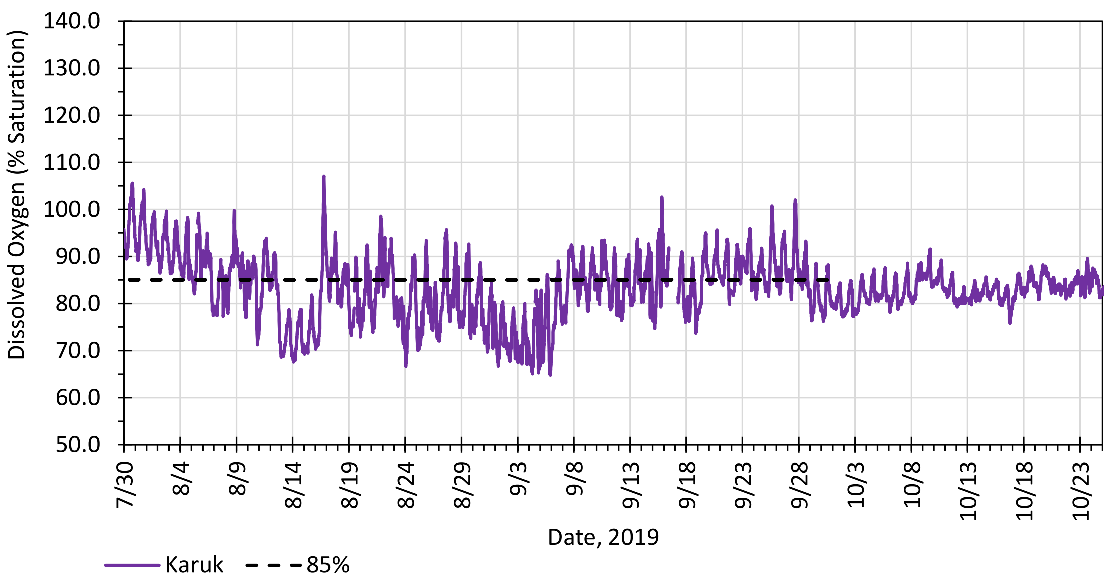


(b)

Figure B-1. Dissolved oxygen data from the PacifiCorp data sonde downstream of Iron Gate Dam (approximately 0.2 river miles downstream from Iron Gate Dam) with (a) dissolved oxygen (mg/L) and (b) dissolved oxygen (percent saturation) and 85 percent saturation threshold (dashed line): July 30 through October 24, 2019.

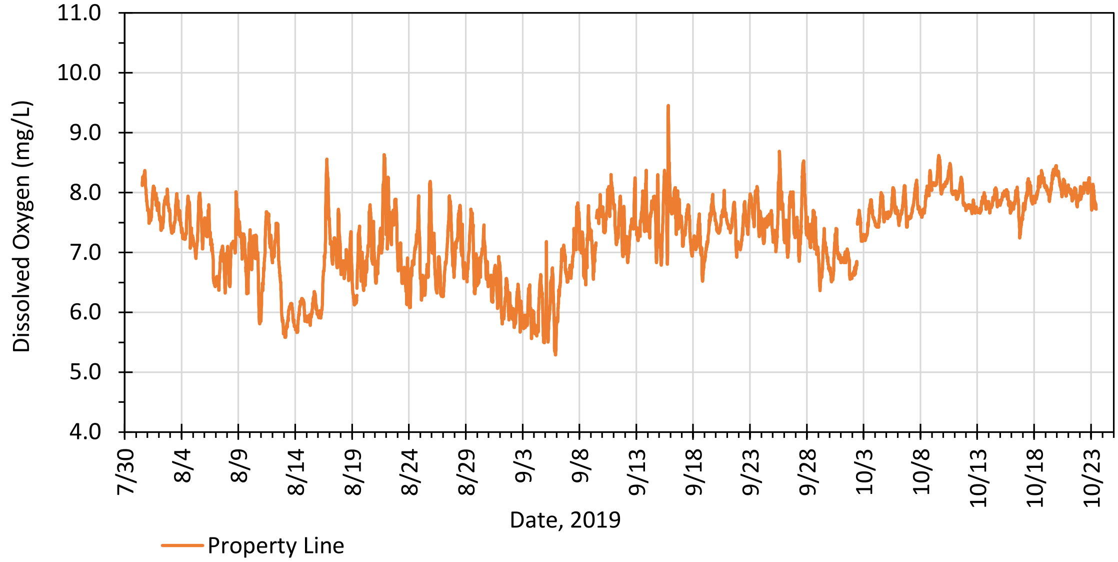


(a)

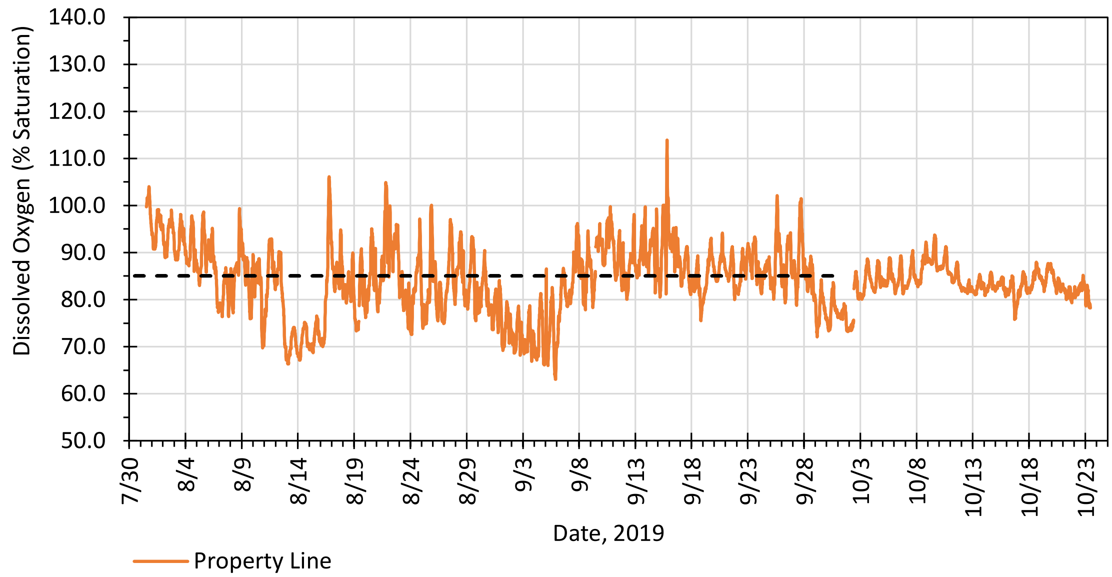


(b)

Figure B-2. Dissolved oxygen data from the Karuk data sonde, approximately 0.5 river miles downstream from Iron Gate Dam with (a) dissolved oxygen (mg/L) and (b) dissolved oxygen (percent saturation) and 85 percent saturation threshold (dashed line): July 30 through October 24, 2019.

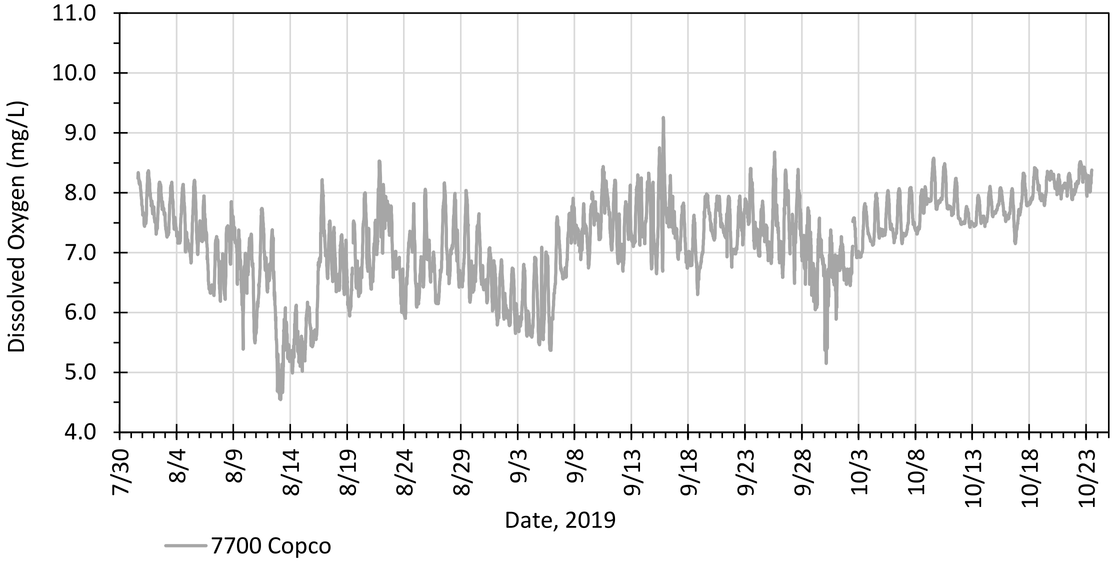


(a)

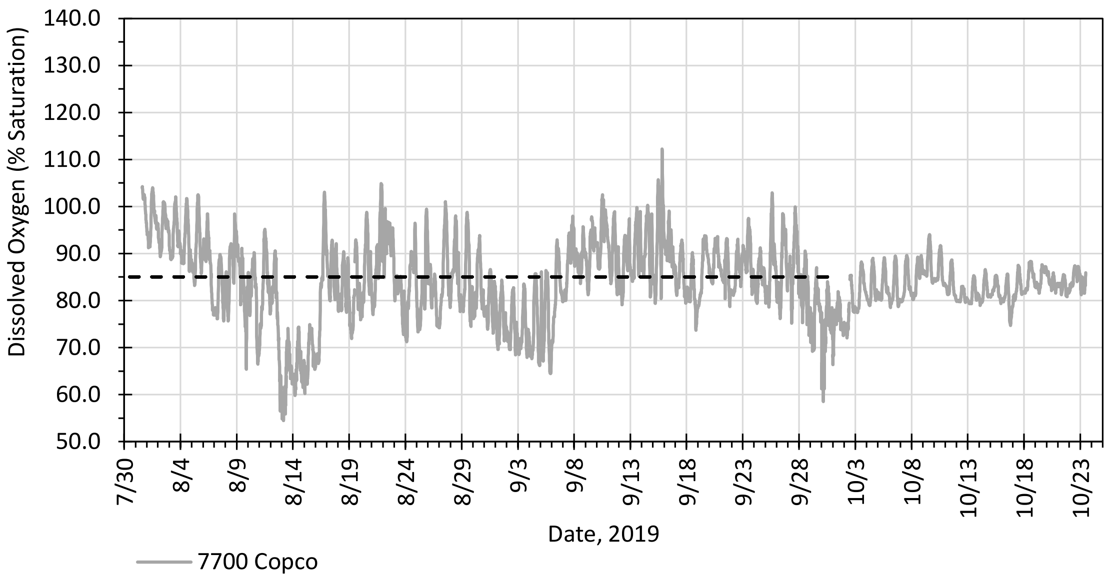


(b)

Figure B-3. Dissolved oxygen data from the Onset U-26 dissolved meter at the PacifiCorp property line, approximately 0.6 river miles downstream from Iron Gate Dam with (a) dissolved oxygen (mg/L) and (b) dissolved oxygen (percent saturation) and 85 percent saturation threshold (dashed line): July 30 through October 24, 2019.

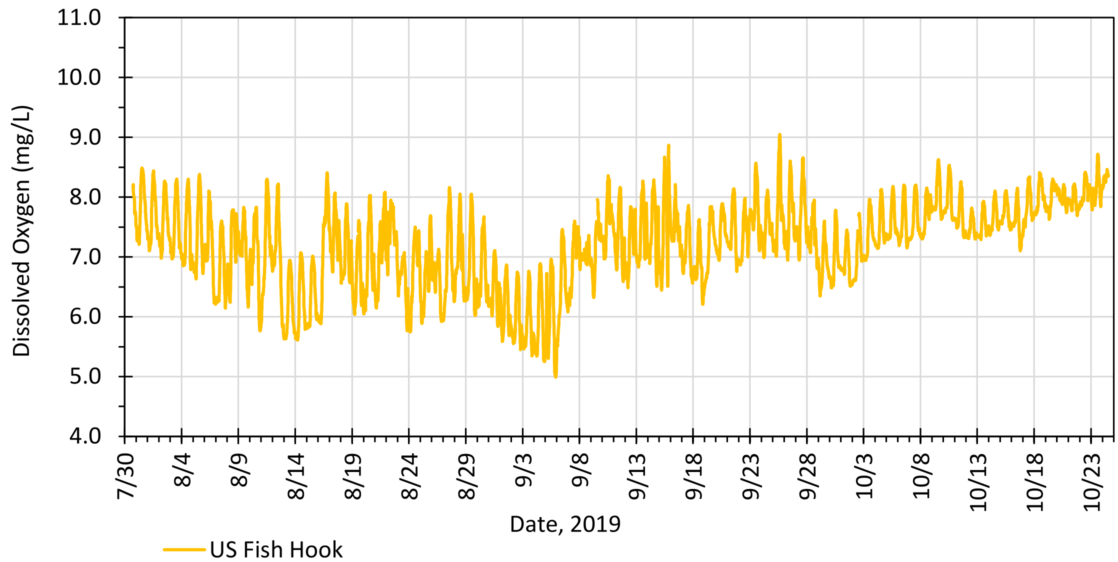


(a)

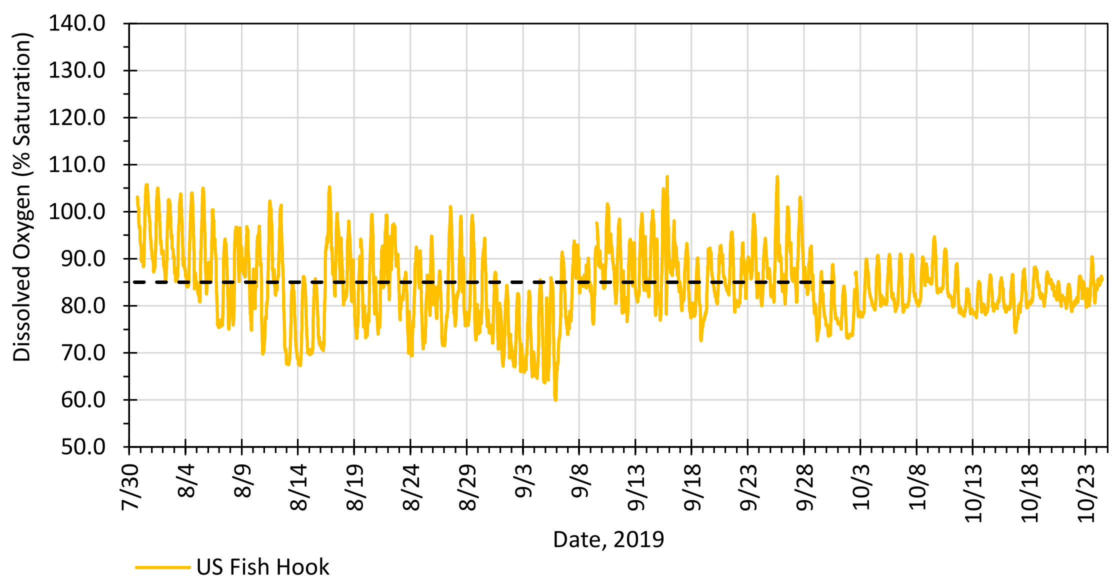


(b)

Figure B-4. Dissolved oxygen data from the Onset U-26 dissolved meter at the 7700 Copco Rd, approximately 1.2 river miles downstream from Iron Gate Dam with (a) dissolved oxygen (mg/L) and (b) dissolved oxygen (percent saturation) and 85 percent saturation threshold (dashed line): July 30 through October 24, 2019.

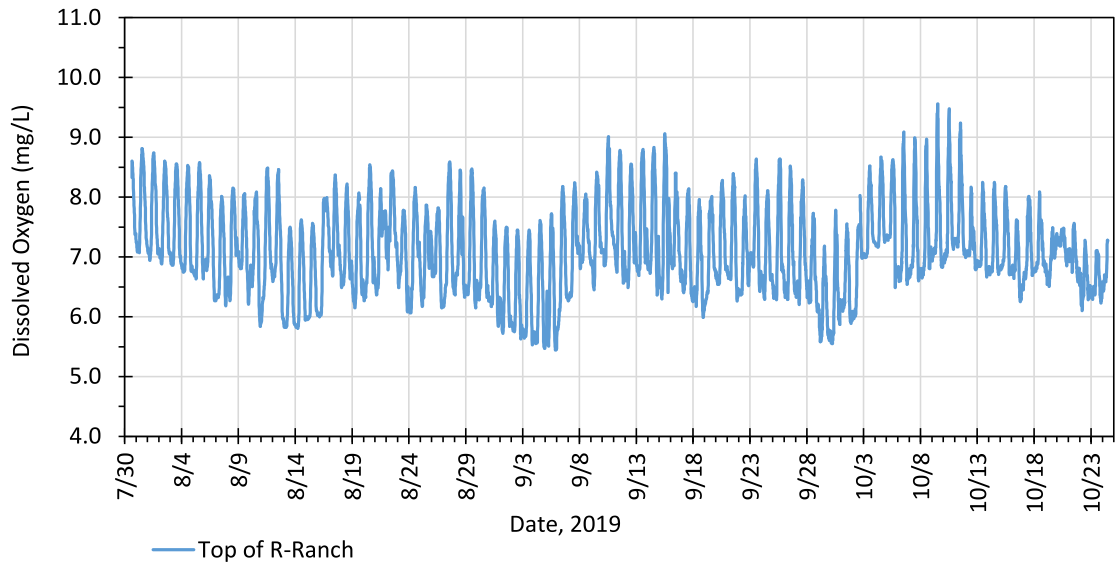


(a)

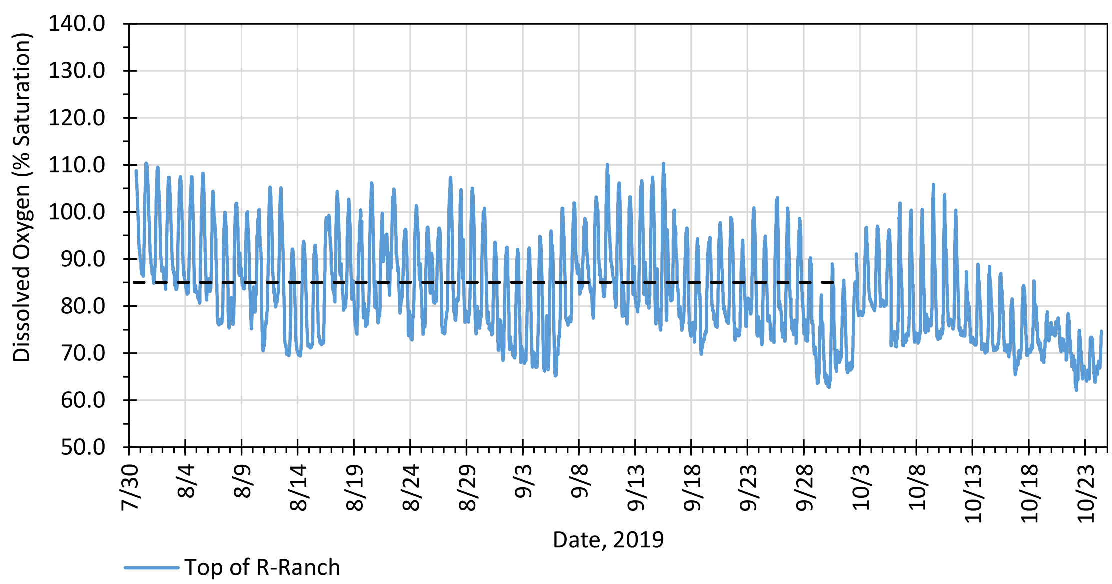


(b)

Figure B-5. Dissolved oxygen data from the Onset U-26 dissolved meter at the upstream of the Blue Heron RV Park (US Fish Hook), approximately 1.4 river miles downstream from Iron Gate Dam with (a) dissolved oxygen (mg/L) and (b) dissolved oxygen (percent saturation) and 85 percent saturation threshold (dashed line): July 30 through October 24, 2019.

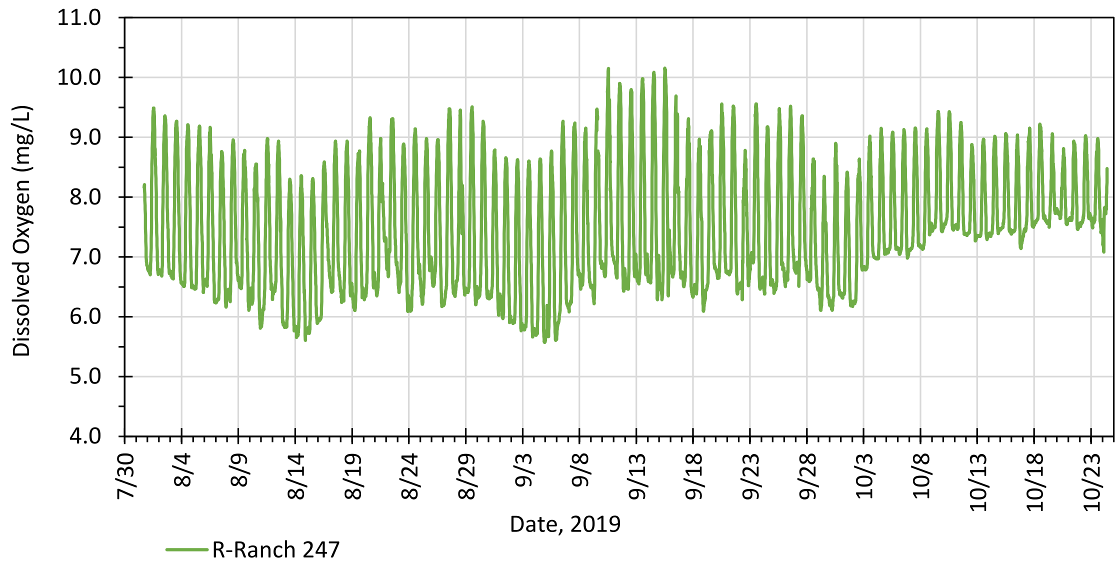


(a)

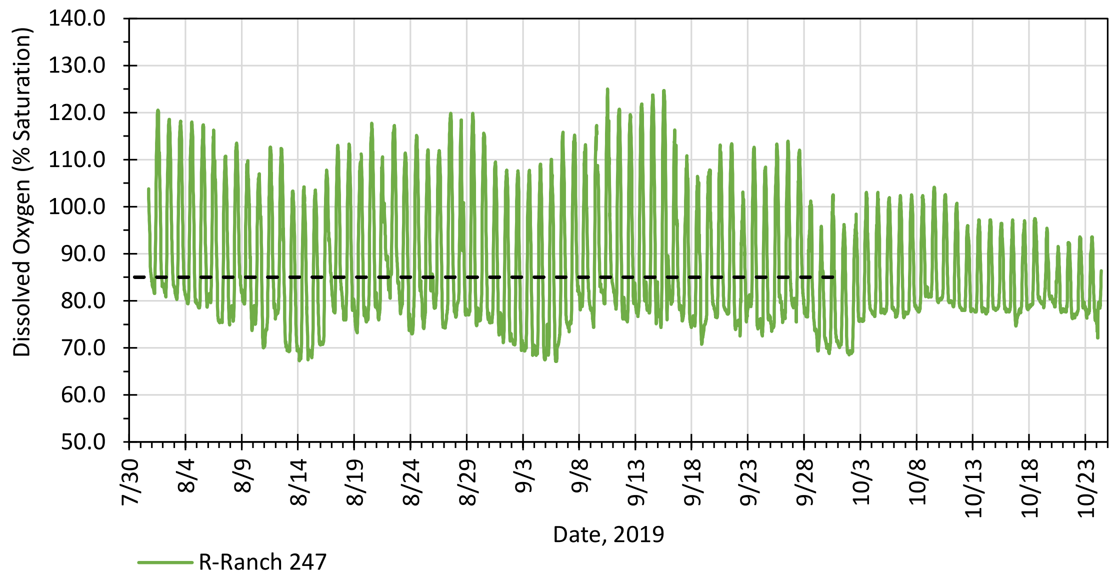


(b)

Figure B-6. Dissolved oxygen data from the Onset U-26 dissolved meter at the upstream end of the R-Ranch, approximately 2.4 river miles downstream from Iron Gate Dam with (a) dissolved oxygen (mg/L) and (b) dissolved oxygen (percent saturation) and 85 percent saturation threshold (dashed line): July 30 through October 24, 2019.

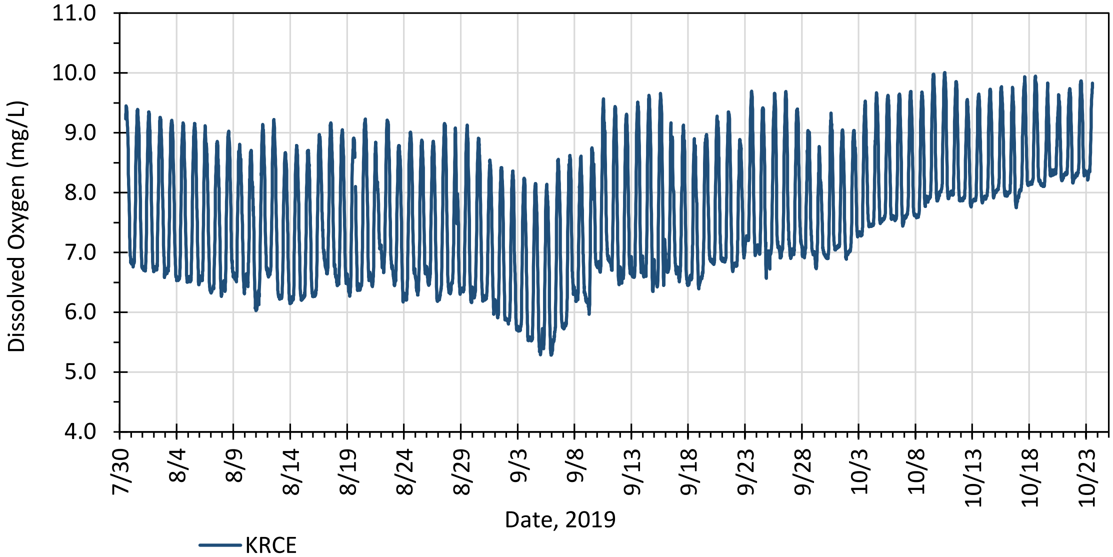


(a)

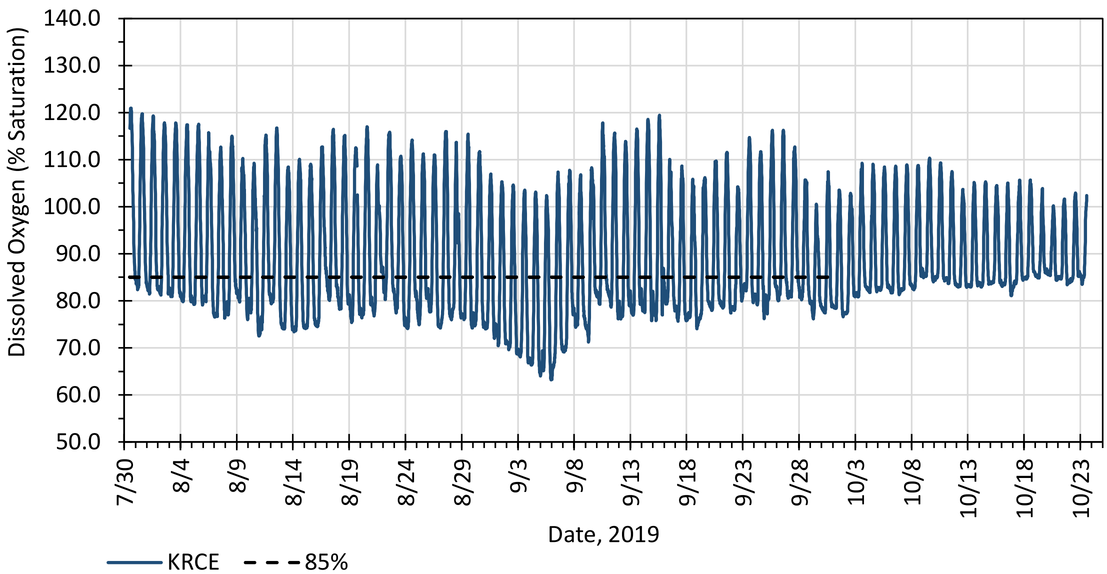


(b)

Figure B-7. Dissolved oxygen data from the Onset U-26 dissolved meter at the R-Ranch campground, site 247, approximately 3.0 river miles downstream from Iron Gate Dam with (a) dissolved oxygen (mg/L) and (b) dissolved oxygen (percent saturation) and 85 percent saturation threshold (dashed line): July 30 through October 24, 2019.

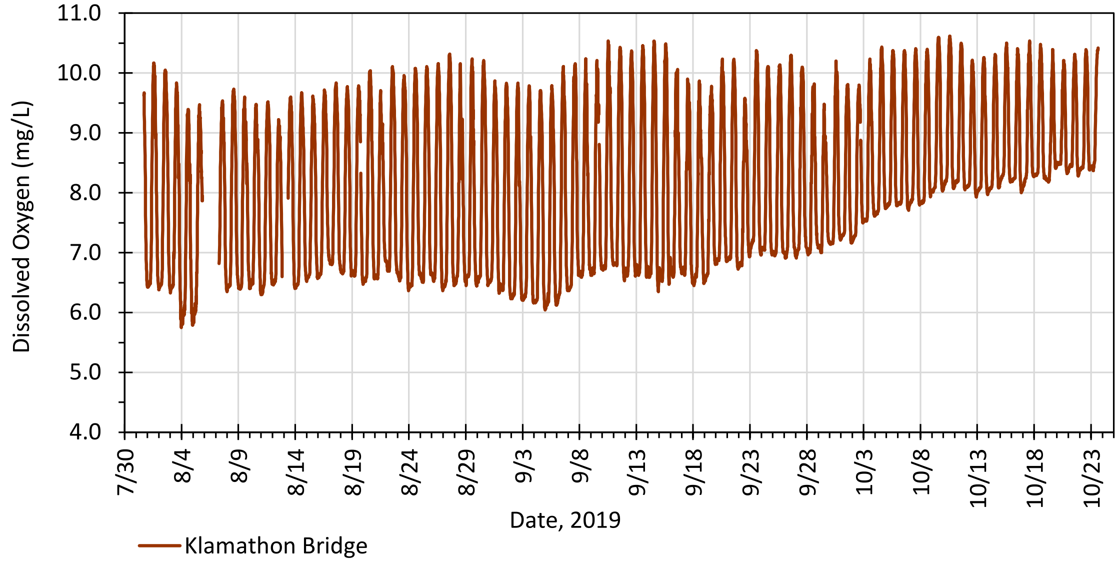


(a)

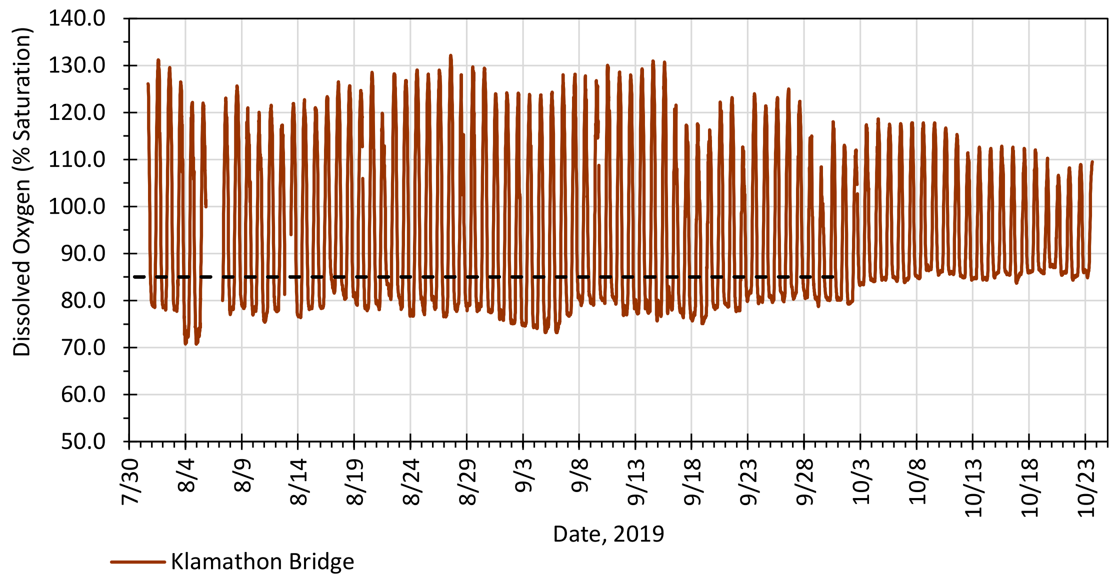


(b)

Figure B-8. Dissolved oxygen data from the Onset U-26 dissolved meter at the Klamath River Country Estates (KRCE) campground, approximately 4.2 river miles downstream from Iron Gate Dam with (a) dissolved oxygen (mg/L) and (b) dissolved oxygen (percent saturation) and 85 percent saturation threshold (dashed line): July 30 through October 24, 2019.



(a)



(b)

Figure B-9. Dissolved oxygen data from the Onset U-26 dissolved meter at the Klamathon Bridge, approximately 5.6 river miles downstream from Iron Gate Dam with (a) dissolved oxygen (mg/L) and (b) dissolved oxygen (percent saturation) and 85 percent saturation threshold (dashed line): July 30 through October 24, 2019. Missing data in early August correspond to periods that the meter was tampered with and pulled out of the water.

B.2. 2019 Continuous Water Temperature data downstream Iron Gate Dam

In addition to DO, Onset U-26 meters and the sonde below Iron Gate (KRBI) collected water temperature data at 15-minute intervals. Water temperatures from 0.6 to 5.6 miles downstream of Iron Gate Dam display temperatures that generally ranged from 20 to 24°C from August through early September, and then dropped with seasonal reduction in solar radiation in the fall, down to 13 to 15°C by late October (Figure B-10). Daily range of water temperatures increases as distance from the dam increases (Figure B-10).

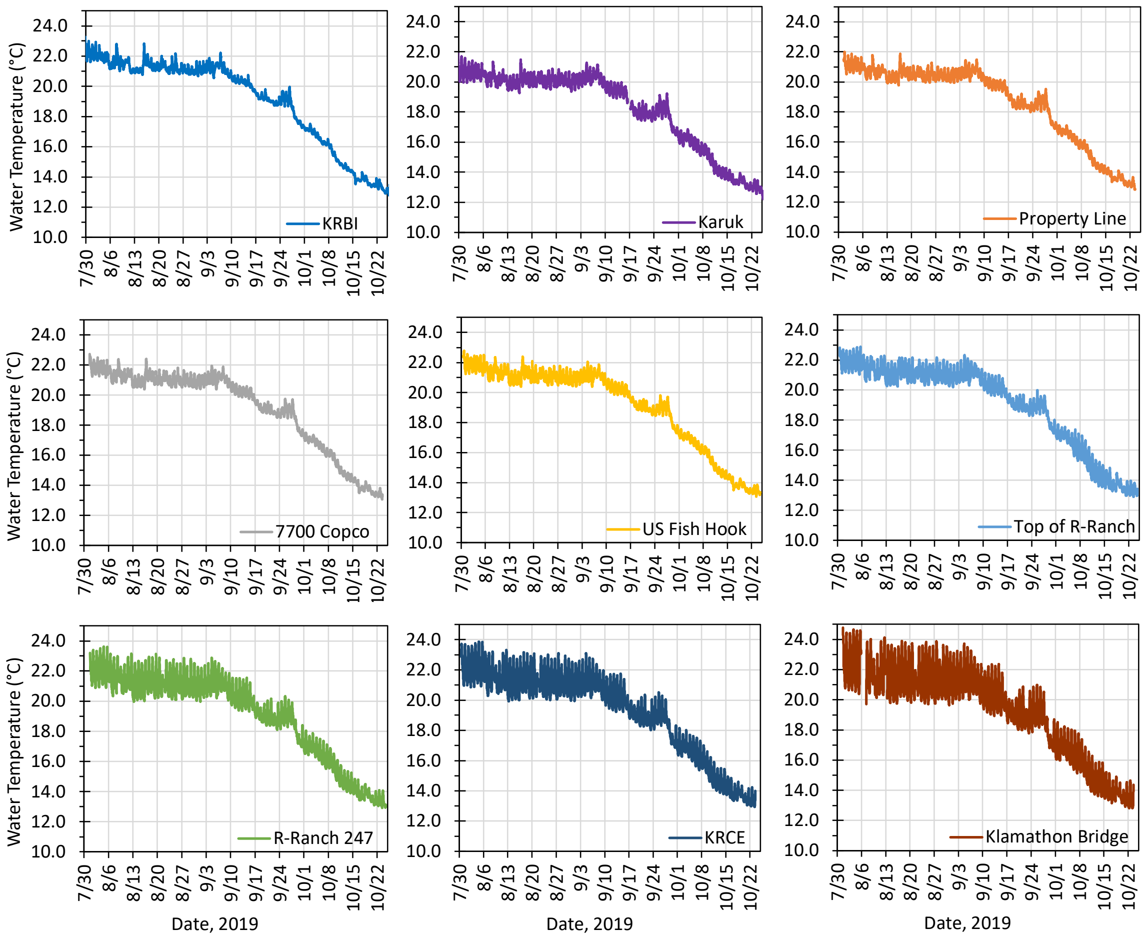
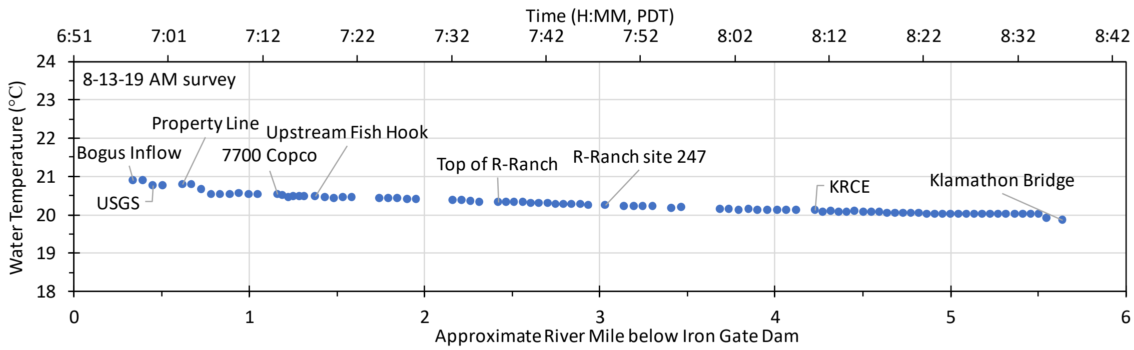


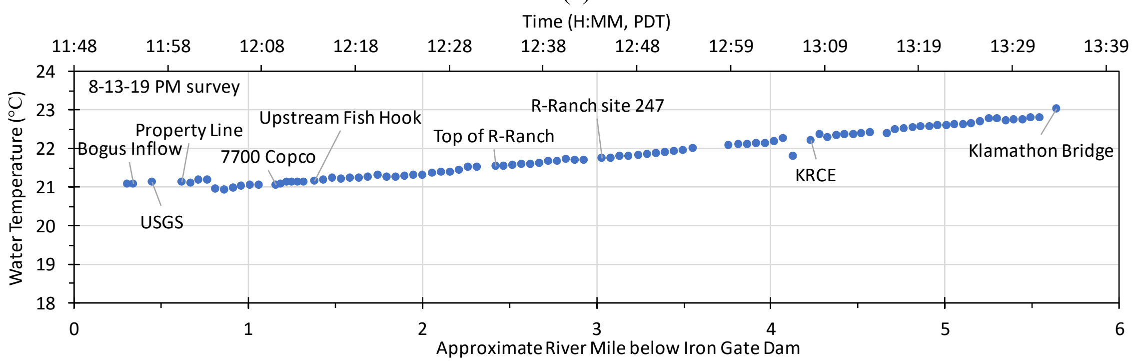
Figure B-10. 15-minute water temperature (°C) at sites downstream of Iron Gate Dam: July 30 through October 24, 2019.

6.1. 2019 Longitudinal Survey Water Temperature data downstream Iron Gate Dam

The data sonde employed during the August 13, 2019 and September 24, 2019 longitudinal surveys also collected water temperature data (Figure B-11 and Figure B-12, respectively). On both survey dates, temperatures decreased from upstream to downstream during the morning survey and increased from upstream to downstream during the afternoon survey.

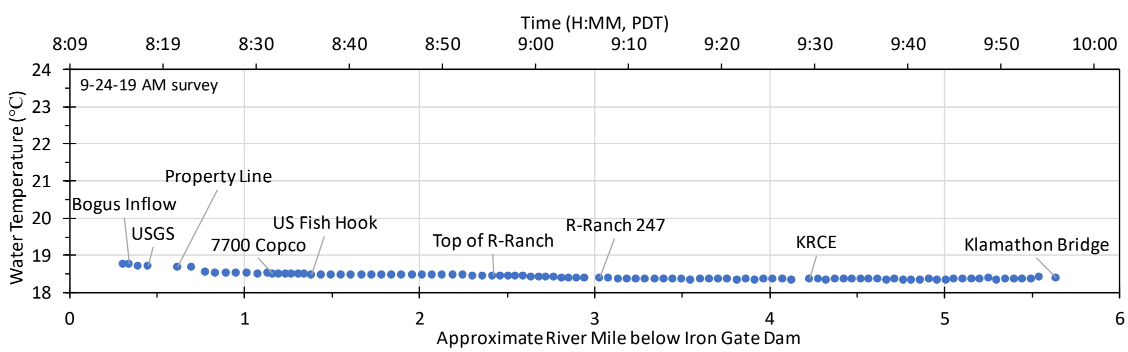


(a)

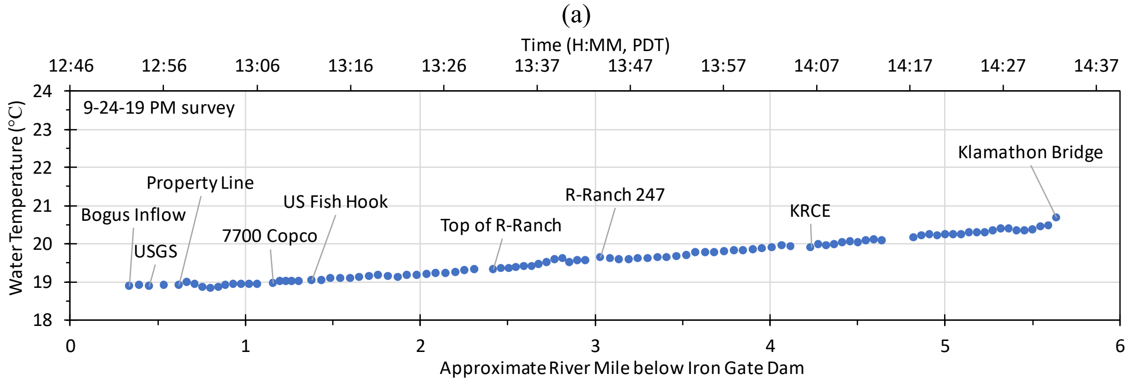


(b)

Figure B-11. Water temperature (°C) collected during (a) morning and (b) afternoon longitudinal surveys: August 13, 2019.



(a)



(b)

Figure B-12. Water temperature (°C) collected during (a) morning and (b) afternoon longitudinal surveys: September 24, 2019.

B.3. 2017 and 2018 Dissolved Oxygen Klamath River Monitoring: PacifiCorp

Dissolved oxygen monitoring prior to 2019 included longitudinal surveys collected in 2017 and the installation of Onset U-26 DO meters in 2018. Biofouling challenges in 2018 continuous data provided valuable insight for the development of the 2019 monitoring plan.

B.3.1. 2017 Longitudinal Surveys

Longitudinal boat surveys were conducted in 2017 from the Lakeview Road Bridge to the CDFW Boat Ramp (this ramp is on river left about 1,800 feet upstream of the confluence of the Klamath River and Cottonwood Creek about 7.3 river miles downstream of Iron Gate Dam) on September 22, 2017 and from the Lakeview Road Bridge to the Klamathon Bridge on September 26 and 28, 2017 (Figure B-13, Figure B-14, Figure B-15, and Figure B-16). During all three surveys, DO percent saturation[10] was above 85 percent by the Klamathon Bridge.

[10] Dissolved oxygen percent saturation values represent site-specific (local) percent saturation. Site-specific dissolved oxygen percent saturation data (local) were calculated using water temperatures, site-specific barometric pressures, and a specific conductance of 141.4 μS/cm.

Figure B-13. Dissolved Oxygen sample site map for longitudinal surveys on September 22, 26, and 28, 2017. Note that the CDFW Boat Ramp is not indicated on the map but is located approximately 1.7 miles below the Klamathon Bridge, just upstream of the mouth of Cottonwood Creek on river right (latitude 42.89158°, longitude -122.53800°).

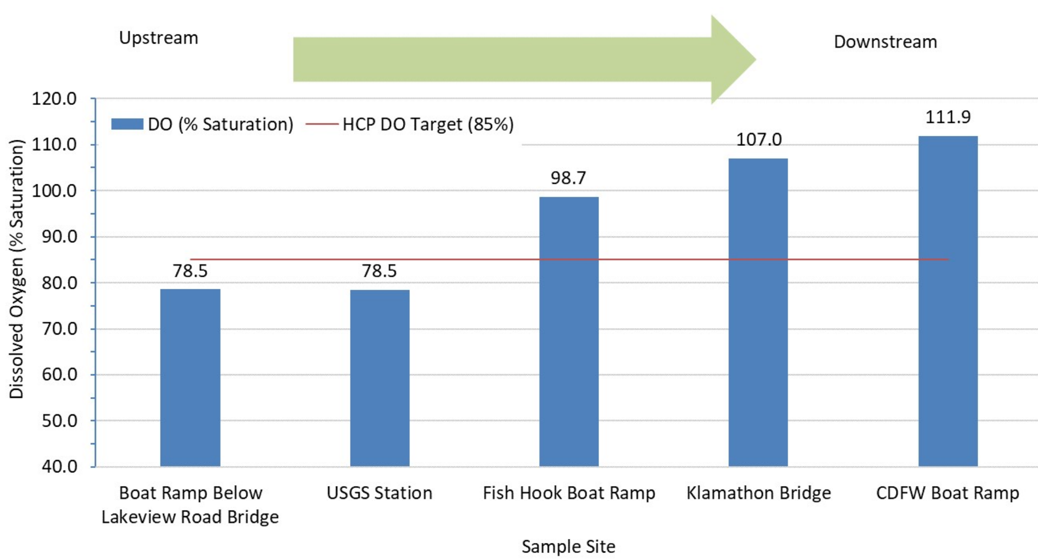


Figure B-14. Dissolved oxygen concentrations (percent saturation) in the Klamath River from Lakeview Road Bridge to the CDFW Boat Ramp collected during longitudinal survey: September 22, 2017 from 11:34 AM to 12:38 PM.

Figure B-15. Dissolved oxygen concentrations (percent saturation) in the Klamath River from Lakeview Road Bridge to Klamathon Bridge collected during longitudinal survey: September 26, 2017 from 9:41 AM to 12:42 PM.

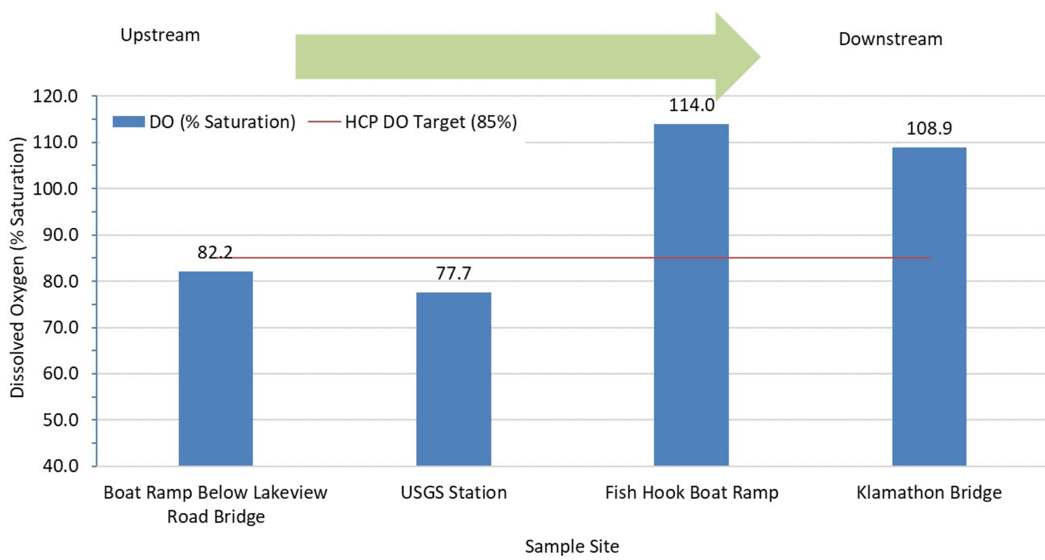


Figure B-16. Dissolved oxygen concentrations (percent saturation) in the Klamath River from Lakeview Road Bridge to Klamathon Bridge collected during longitudinal survey: September 28, 2017 from 12:32 PM to 1:20 PM.

B.3.2. 2018 Continuous Dissolved Oxygen Monitoring

In 2018, Onset U-26 meters were deployed at four locations in the Klamath River downstream of Iron Gate Dam from August 16 through October 16, 2018 and collected dissolved oxygen (mg/L) and water temperature data. Dissolved oxygen percent saturation values were calculated[11]. Biofouling was not removed from Onset DO meters during this period, except when removed in October. The KRBI sonde data were compared to preliminary uncorrected Onset U-26 DO meter data; similar to 2019 data, DO concentrations and percent saturation generally increased, and demonstrated increased diel ranges, in the downstream direction (Figure B-17 and Figure B-18). As in 2019, DO percent saturation reached 85 percent each day at the Klamathon Bridge site, for all days monitored. Biofouling was apparent at the Top of R-Ranch and Mile Marker 4.0 (MM 4.0) sites in late September, and potentially again in early October. Biofouling is the suspected cause for the DO levels at these two sites because there are not corresponding changes in DO concentrations at other sites at the same time. Because of the biofouling issues all of the 2018 data is considered preliminary.

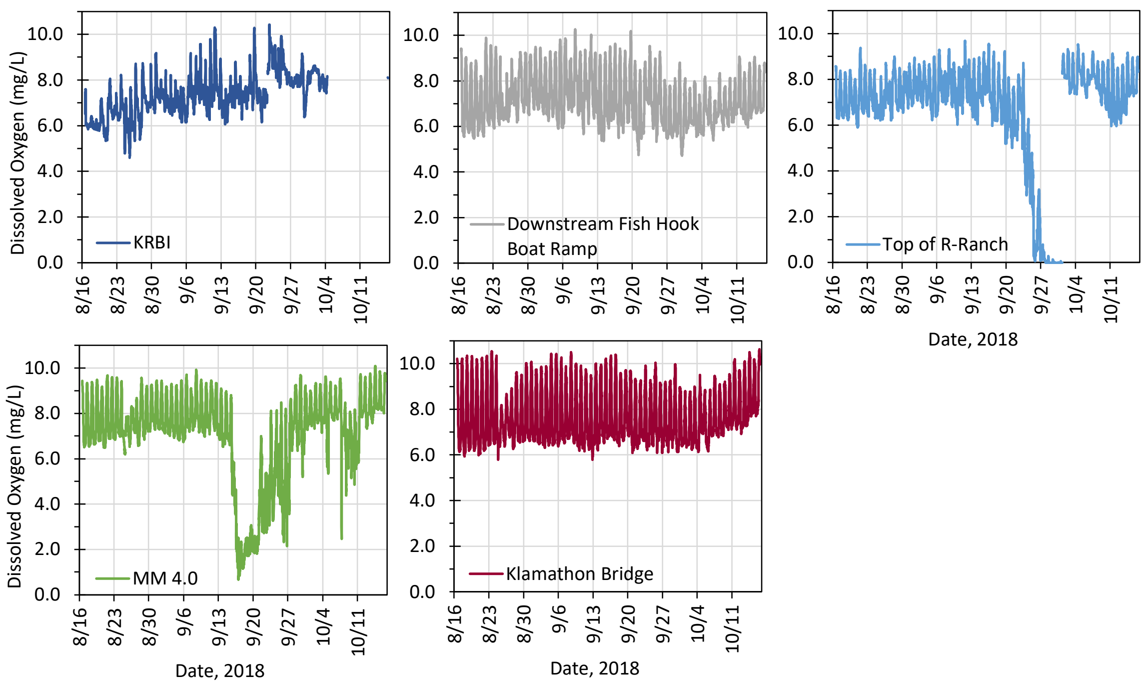


Figure B-17. Preliminary uncorrected dissolved oxygen (mg/L) data downstream of Iron Gate Dam: August 16 through December 16, 2018. Data were not corrected for biofouling and large crashes (Top of R-Ranch and MM 4.0 in September, and MM 4.0 in October) are likely due to biofouling.

[11] Dissolved oxygen percent saturation values represent site-specific (local) percent saturation. Site-specific dissolved oxygen percent saturation data (local) were calculated using water temperatures, site-specific barometric pressures, and a specific conductance of 141.4 μS/cm.

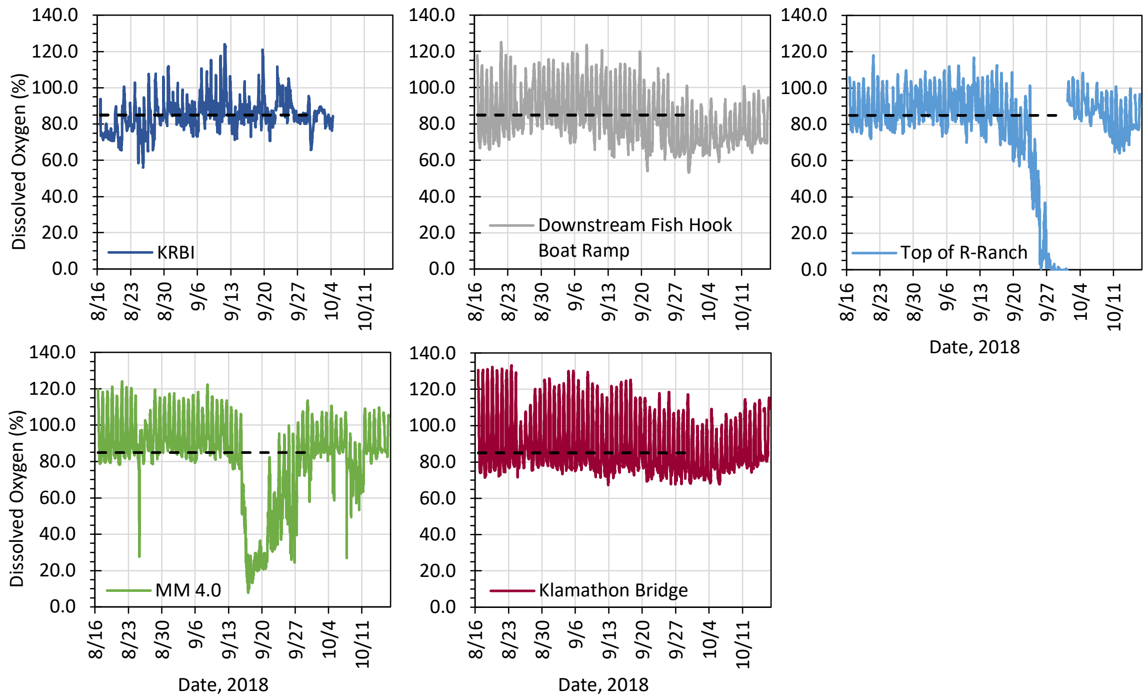


Figure B-18. Preliminary uncorrected dissolved oxygen (percent saturation) data downstream of Iron Gate Dam and 85 percent saturation (dashed line): August 16 through December 16, 2018. Data were not corrected for biofouling and large crashes (Top of R-Ranch and MM 4.0 in September, and MM 4.0 in October) are likely due to biofouling.