BIG CREEK DISSOLVED OXYGEN

Dissolved oxygen is an important indicator of aquatic ecosystem health and as such is a key water-quality parameter measured in many water studies and is a guiding regulatory standard for evaluating and protecting stream health. Arkansas Pollution Control and Ecology Commission Regulation 2.505 establishes the standards for surface-water dissolved oxygen values.

Regulation 2.505 Establishing Dissolved Oxygen Standards for Surface Waters of the State of Arkansas

Arkansas Pollution Control and Ecology Commission Regulation No. 2, as amended by Pollution Control and Ecology Commission # 014.00-002 from Arkansas Department of Environmental Quality (ADEQ), 2018, pages 45-48 of "Assessment methodology: For the Preparation of the 2016 Integrated Water Quality Monitoring and Assessment Report pursuant to the Clean Water Act Sections 303(d) and 305(b). Final Draft 2017." 72 pages total. Available at https://www.adeq.state.ar.us/water/planning/integrated/assessment/pdfs/final-draft-2018-am_10oct2017-(2).pdf provides the specific dissolved oxygen standard for surface waters in the State.

Dissolved oxygen levels are specified in water quality standards. In the 2 to 5 mg/L range, most fish and aquatic life will survive, but will not thrive. At less than 2 mg/L, mortality begins.

The following dissolved oxygen standards are applicable for rivers and streams.

Watershed area, mi^2	Ozark Highlands		Boston Mountains	
	Primary [1]	Critical [2]	Primary [1]	Critical [2]
	---------- mg/L ----------			
<10 mi^2 watershed	6	2	6	2
10 to 100 mi^2 watershed	6	5	None	None
>100 mi^2 watershed	6	6	6	6

1. Primary season is defined as when water temperatures are at or below 22 °C.
2. Critical season is defined as when water temperatures are greater 22 °C.

In streams with watersheds of less than 10 mi^2, it is assumed that insufficient water exists to support aquatic life during the critical season. During this time, a dissolved oxygen standard of 2 mg/L will apply to prevent nuisance conditions. However, field verification is required in areas suspected of having significant groundwater flows or enduring pools, which may support unique aquatic biota. In such waters, the critical season standard for the next size category of stream shall apply.

All streams with watersheds of less than 10 mi^2 are expected to support aquatic life during the primary season when stream flows, including discharges, equal or exceed 1 cubic foot per second (cfs). However, when site verification indicates that aquatic life exists at flows below 1 cfs, such aquatic biota will be protected by the primary standard (refer to the State of Arkansas Continuing Planning Process for field verification requirements).

Also, in these streams with watersheds of less than 10 mi^2, where waste discharges are 1 cfs or more, they are assumed to provide sufficient water to support aquatic life and, therefore, must meet the dissolved oxygen standards of the next size category of streams.

For purposes of determining effluent discharge limits, the following conditions apply:

A. The primary season dissolved oxygen standard is to be met at a water temperature of 22°C (71.5°F) and at the minimum stream flow for that season. At water temperatures of 10°C (50°F), the dissolved oxygen standard is 6.5 mg/L.
B. During March, April and May, when background stream flows are 15 cfs or higher, the dissolved oxygen standard is 6.5 mg/L in all areas except the Delta Ecoregion, where the primary season dissolved oxygen standard will remain at 5 mg/L.
C. The critical season dissolved oxygen standard is to be met at maximum allowable water temperatures and at Q7-10 flows. However, when water temperatures exceed 22°C (71.6°F), a 1 mg/L diurnal depression will be allowed below the applicable critical standard for no more than 8 hours during any 24-hour period.

Field Determination and Methodology

Dissolved oxygen and temperature are determined *in-situ* using a luminescent dissolved oxygen sensor integrated to a Hydrolab HL4 sonde[1]. In-situ measurement entails no holding time for samples, and the act of collecting a sample can change the oxygen level, a direct probe reading is often the preferred method. The probe is air calibrated at monthly intervals when data are downloaded from the sonde data logger. Data quality are assured through recording calibration accuracy and conducting a field duplicate to determine precision. See U.S. EPA Field Measurement of Dissolved Oxygen for details https://www.epa.gov/sites/production/files/2017-07/documents/field_do_measurement106_af.r4.pdf. Sonde readings were recorded every hour for the time they were deployed in Big Creek.

Big Creek Dissolved Oxygen

The following tables and Figures detail the dissolved oxygen concentration in Big Creek upstream of the C&H farm October 22 to November 13, 2014 and downstream of the farm from September 9 to November 11, 2014, April 10 to October 16, 2015, and May 16 to December 11, 2017.

Measurements upstream of the farm were not taken after 2014 due to the sonde probe being dislodged and lost during a large storm even in the spring of 2015. It was not replaced until early 2018, when a secure site on the low-water bridge at the upstream site on Big Creek was made available.

Measurements at the downstream site were not taken in 2016, again due to loss of the sonde at that site during an early spring storm event. Loss of the two sonde units are indicative of the significant amount of scouring and stream bed modification that can take place in large storm events. Also, measurements were not recorded between September 16 and October 17, 2017 due the sonde malfunctioning.

[1] Mention of trade names does not imply endorsement by the Division of Agriculture, University of Arkansas Systems. Information on the Hydrolab HL4 sonde is available at http://www.ott.com/products/water-quality-2/hydrolab-hl4-multiparameter-sonde-54/

Diurnal and seasonal fluctuations in dissolved oxygen concentrations are apparent from measurements in Big Creek. See Figures 1 through 8. The diurnal fluctuations in dissolved oxygen concentration are typically a function of photosynthesis during daylight hours (which releases oxygen); removal of dissolved oxygen by microbial respiration (satisfying microbial and chemical oxygen demands, either in the water column or through interaction with the bed sediments); and exchange of oxygen at the water surface (i.e., reaeration) (O'Connor and Di Toro, 1970[2]; Williams et al., 2000[3]).

The diurnal and seasonal fluctuations of dissolved oxygen concentration are clearly dependent on many factors (Williams et al., 2000[3]). The influence of water column temperature on oxygen solubility can be eliminated by converting dissolved oxygen concentration in mg/L to % saturation. See Figures 9 to 12. Additional breaks in dissolved oxygen concentrations were determined with flow less and greater than 15 cfs for monitoring in 2014, 2015, and 2017 and given in Table 2.

Dissolved oxygen was measured at both upstream and downstream from October 22 to November 13, 2014 and is presented in Figures 13 to 18. Finally, dissolved oxygen at the USGS Carver gaging station is presented in Figure 19 for June 3, 2014 to May 1, 2017.

The information on dissolved oxygen in Big Creek downstream of the C&H Farm at USGS 07055790 Big Creek near Mt. Judea, given here is made available to ADEQ and on the BCRET website. Interpretation of dissolved oxygen concentrations in terms of water quality standards is deferred to ADEQ.

[2] O'Connor, D.J., and D.M. Di Toro. 1970. Photosynthesis and oxygen balance in streams. J. Sanit. Eng. Div. ASCE, 98:547-571.

[3] Williams, R.J., C. White, M.L. Harrow, and C. Neal. 2000. Temporal and small-scale spatial variations of dissolved oxygen in the River Thames, Pang and Kennet, UK. Sci. Total. Environ. 251/252:497-510.

Table 1. Big Creek Dissolved Oxygen concentrations.

Metric	Upstream [1]	Downstream [2]				
	10/22/2014 – 11/13/2014	10/22/2014 – 11/13/2014	9/9/2014 – 11/13/2014	4/8/2015 – 10/16/2015	5/16/2017 - 12/11/2017	9/9/2014 – 12/11/2017
Average	9.36	8.92	8.57	8.73	8.63	8.66
Minimum	6.78	6.67	5.73	5.01	5.84	5.01
Maximum	11.58	12.42	12.42	12.92	14.04	14.04
Median	9.49	8.57	8.27	8.53	8.44	8.44
Observations	525		1,557	4,524	4,093	10,175

1. Watershed area is 27.01 miles^2.
2. Watershed area is 40.89 miles^2.

Table 2. Big Creek Dissolved Oxygen concentrations downstream of C&H, as a function of stream temperature.

Metric	9/9/2014 – 11/13/2014		4/10/2015 – 10/16/2015		5/16/2017 - 12/11/2017		9/9/2014 – 12/11/2017	
	Temperature	Dissolved oxygen	Temperature	Dissolved oxygen	Temperature	Dissolved oxygen	Temperature	Dissolved oxygen
	°C	mg/L	°C	mg/L	°C	mg/L	°C	mg/L
All observed water temperatures								
Average	16.87	8.57	17.98	8.73	18.38	8.63	17.97	8.66
Minimum	7.46	5.73	8.53	5.01	8.49	5.84	7.46	5.01
Maximum	26.46	12.42	26.69	12.92	26.42	14.04	26.69	14.04
Median	16.98	8.28	18.50	8.53	18.65	8.44	18.19	8.45
Observations	1,557		4,525		4,093		10,175	
Observations <6 mg/L DO	8		47		21		74	
Observations <6 mg/L DO, %	0.51		1.04		0.51		0.73	
Water temperature > 22 °C								
Average	23.03	10.78	23.32	9.62	23.16	9.40	23.23	9.56
Minimum	22.04	7.68	22.00	6.09	22.00	6.15	22.00	6.09
Maximum	26.46	11.62	26.69	12.26	26.42	13.19	26.69	13.13
Median	22.66	10.85	23.11	9.87	22.85	9.73	22.95	9.86
Observations	48		523		519		1,090	
Observations <6 mg/L DO	0		0		0		0	

Metric	9/9/2014 – 11/13/2014		4/10/2015 – 10/16/2015		5/16/2017 - 12/11/2017		9/9/2014 – 12/11/2017	
	Flow	Dissolved oxygen	Flow	Dissolved oxygen	Flow	Dissolved oxygen	Flow	Dissolved oxygen
	cfs	mg/L	cfs	mg/L	cfs	mg/L	cfs	mg/L
	Stream flow <15 cfs							
Average	5.08	8.54	3.51	8.48	4.80	8.44	4.43	8.48
Minimum	2.41	5.73	1.44	5.74	1.06	5.72	1.06	5.72
Maximum	14.10	12.42	14.10	12.90	14.60	14.04	14.60	14.04
Median	3.62	8.27	2.79	8.20	3.40	8.15	3.19	8.19
Observations	1340		2006		2634		5980	
	Stream flow >15 cfs							
Average	64.40	8.75	190.63	8.92	127.61	8.97	162.18	8.93
Minimum	15.00	6.96	15.00	5.01	15.50	6.61	15.00	5.01
Maximum	369.00	11.67	14600.00	12.92	10600.00	13.75	14600.00	13.75
Median	45.40	8.28	84.00	8.89	44.70	8.86	58.30	8.85
Observations	217		2519		1459		4195	

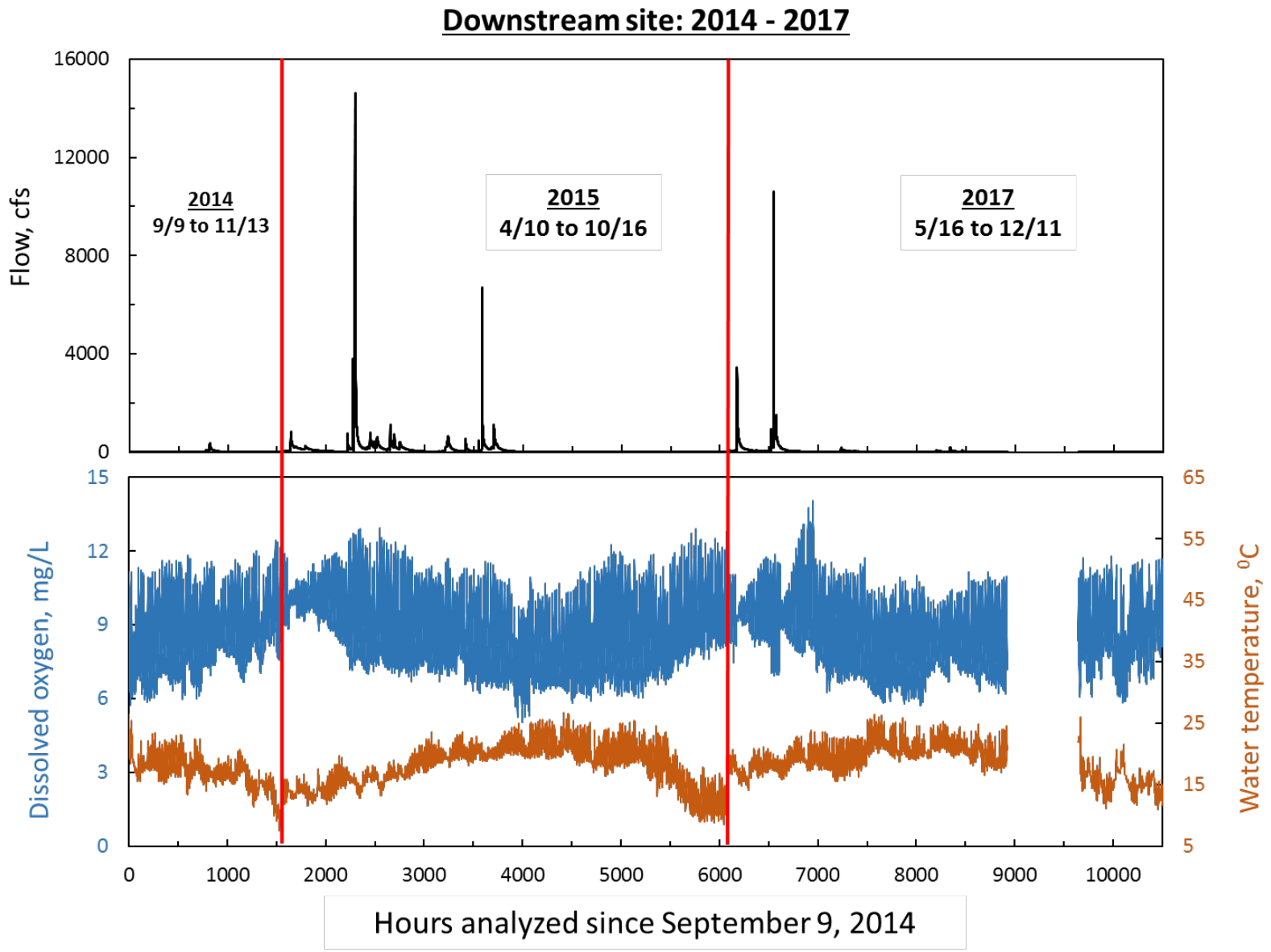

Figure 1. Flow, water temperature, and dissolved oxygen concentration downstream of the C&H Farm between September 9, 2014 and December 11, 2017.

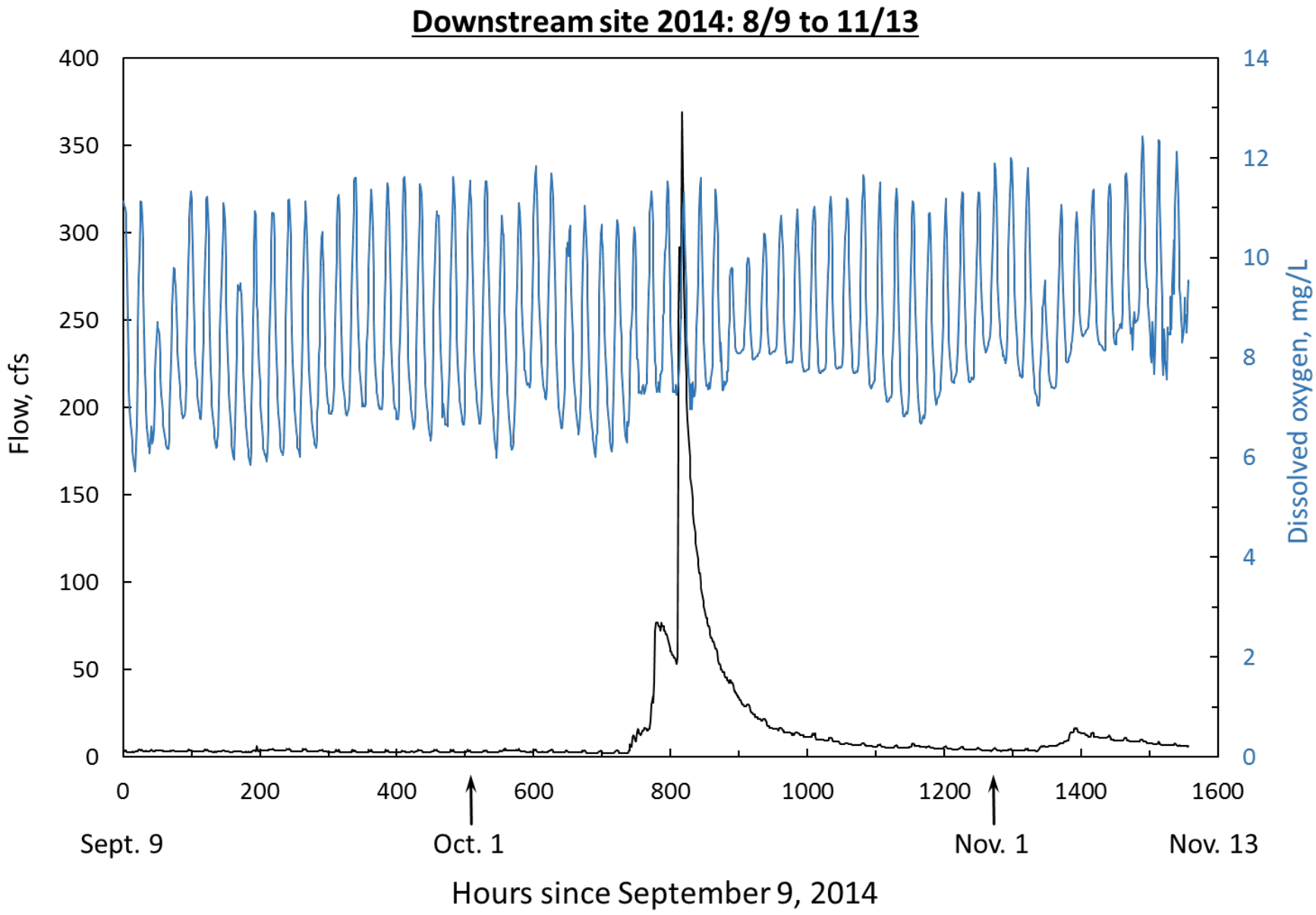

Figure 2. Flow and dissolved oxygen concentration downstream of the C&H Farm between September 9 and November 13, 2014.

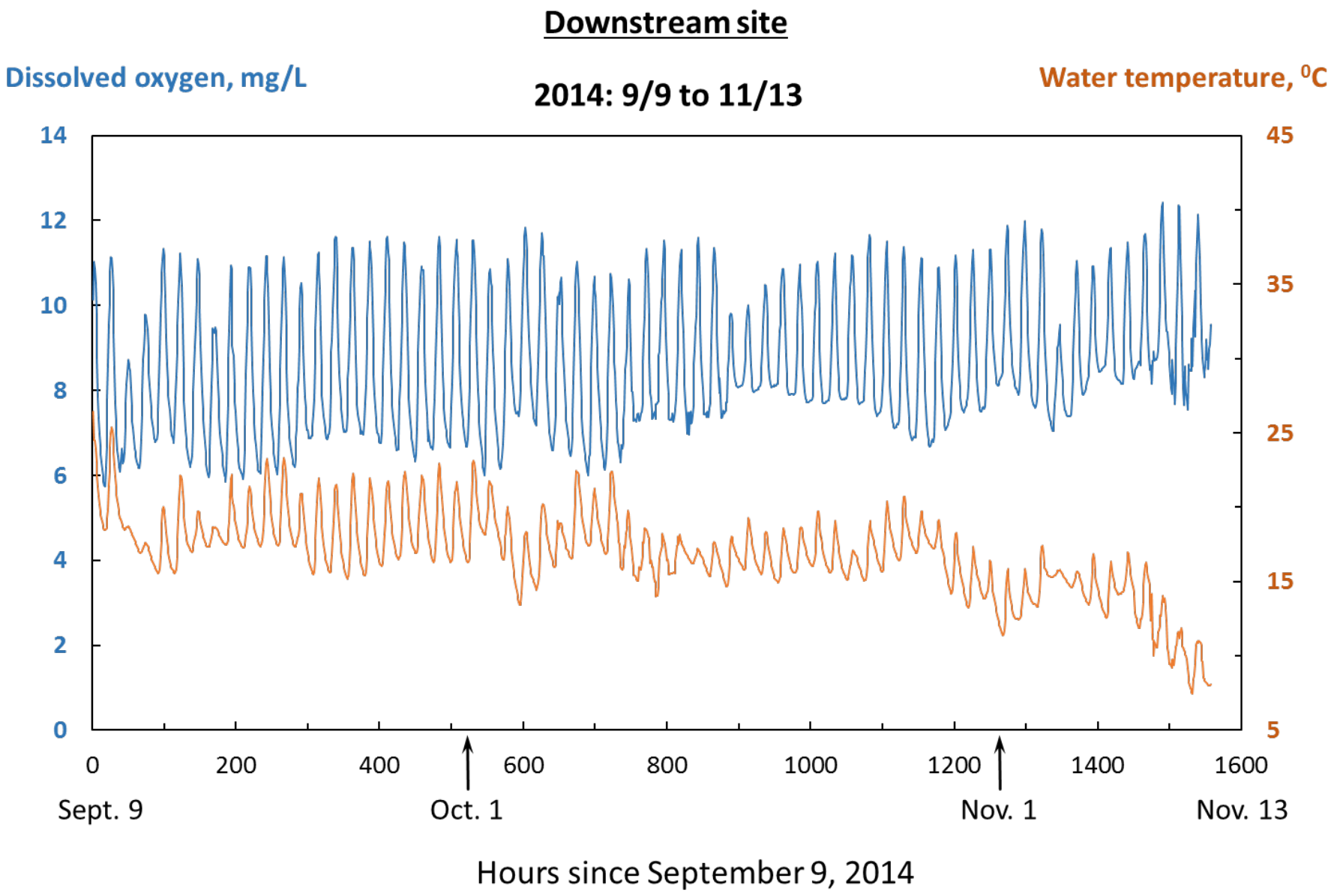

Figure 3. Water temperature and dissolved oxygen concentration downstream of the C&H Farm between September 9 and November 13, 2014.

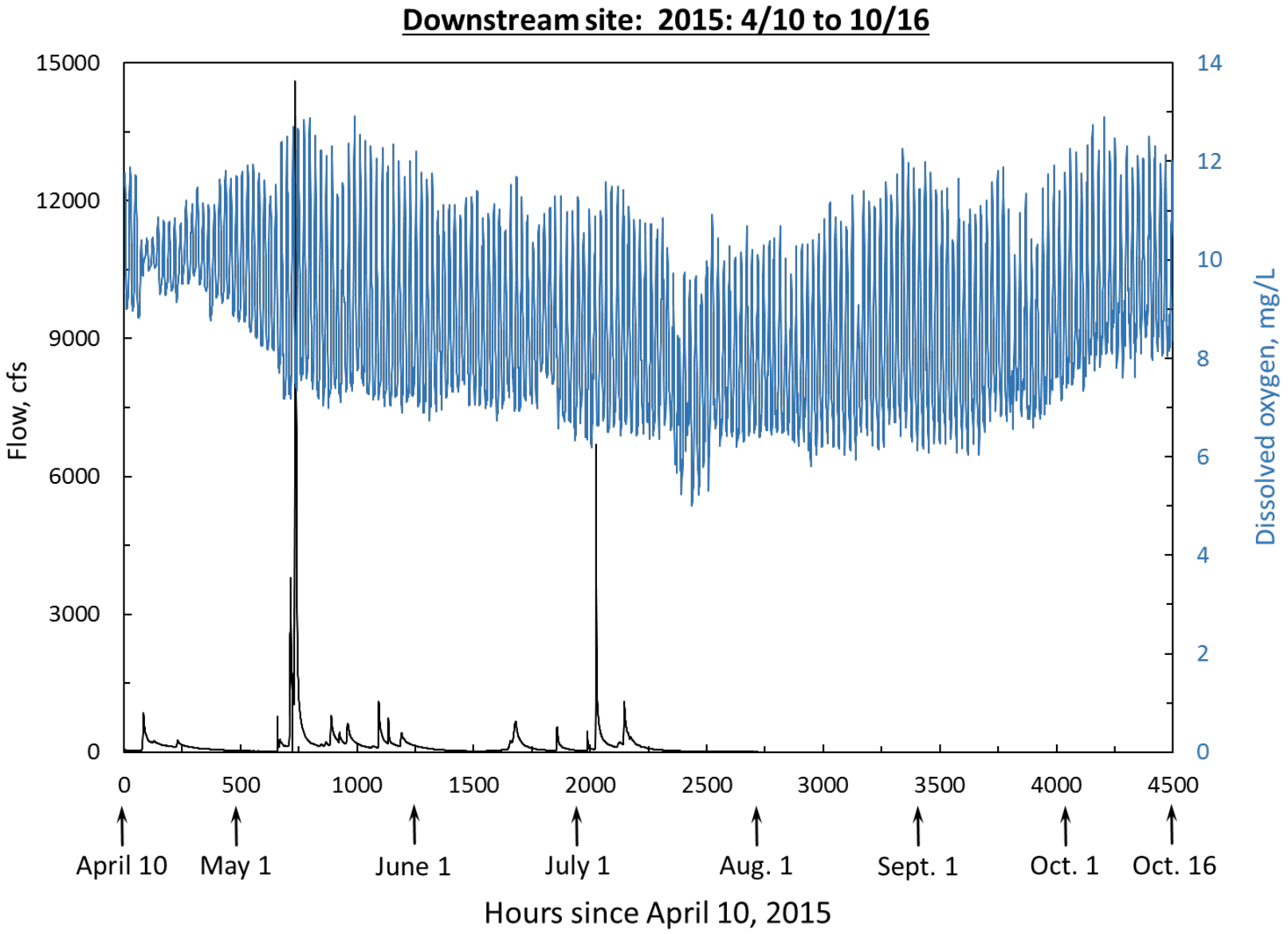

Figure 4. Flow and dissolved oxygen concentration downstream of the C&H Farm between S April 10 and October 16, 2015.

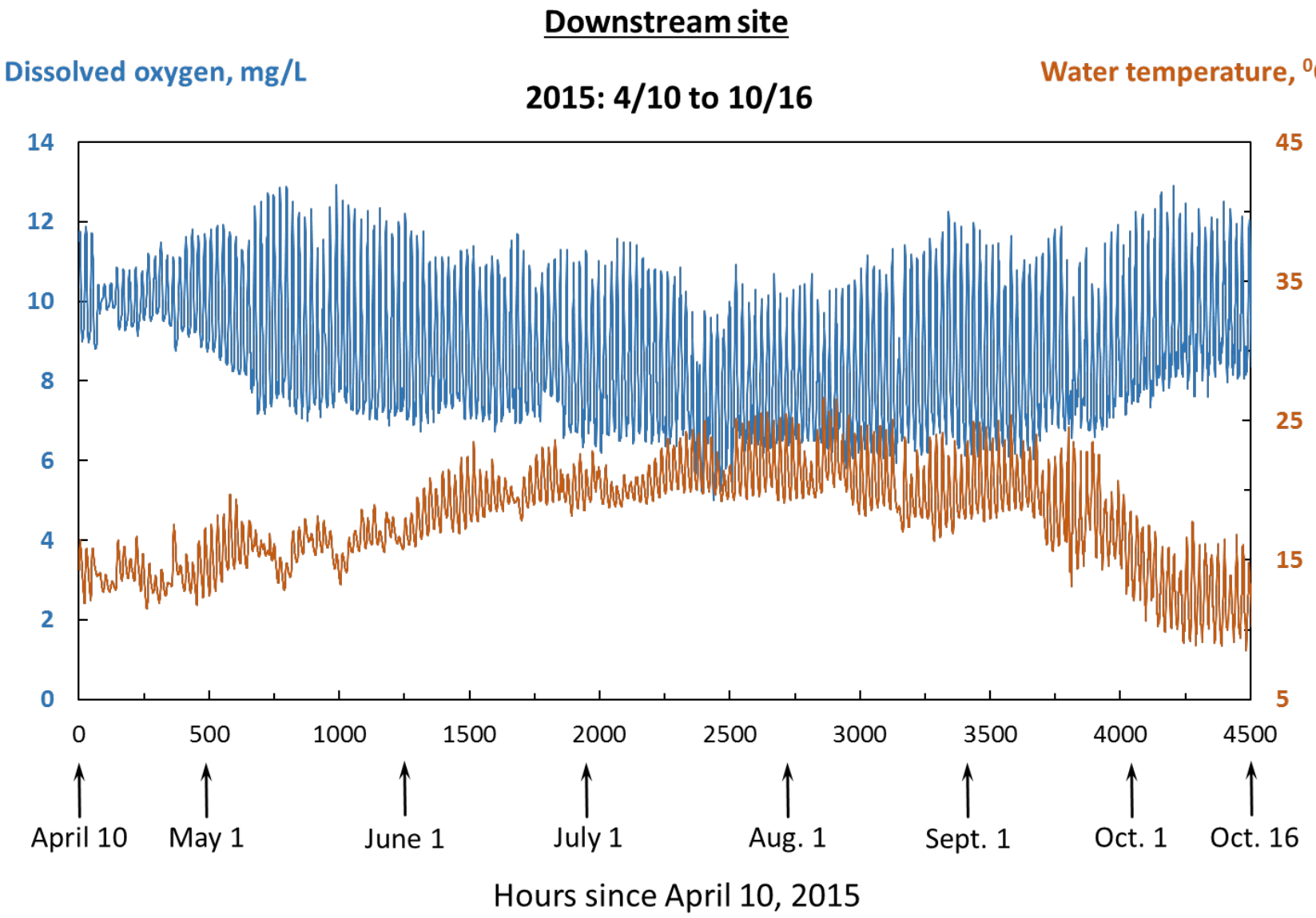

Figure 5. Water temperature and dissolved oxygen concentration downstream of the C&H Farm between April 10 and October 16, 2015.

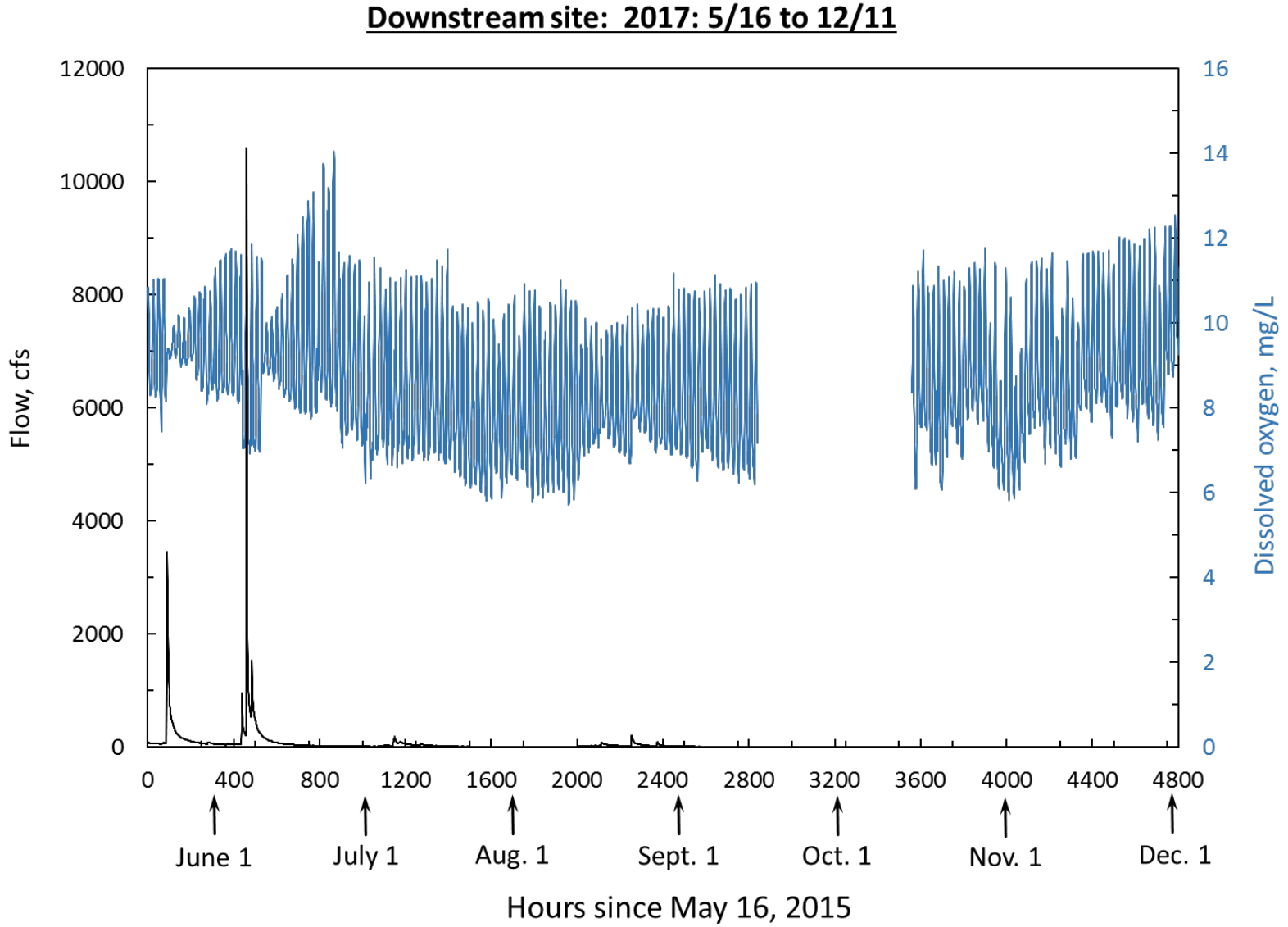

Figure 6. Flow and dissolved oxygen concentration downstream of the C&H Farm between May 16 and December 11, 2017.

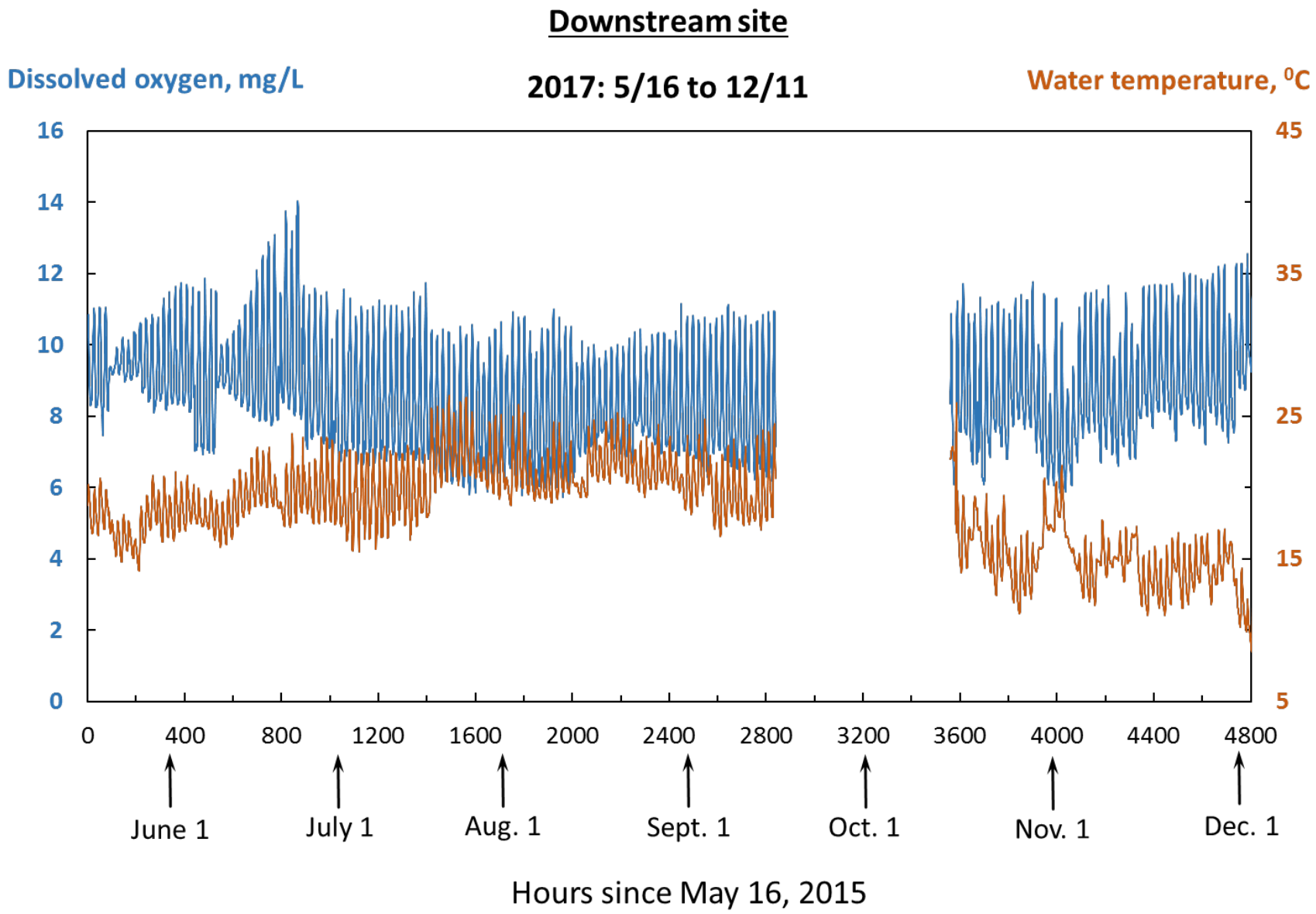

Figure 7. Water temperature and dissolved oxygen concentration downstream of the C&H Farm between May 16 and December 11, 2017.

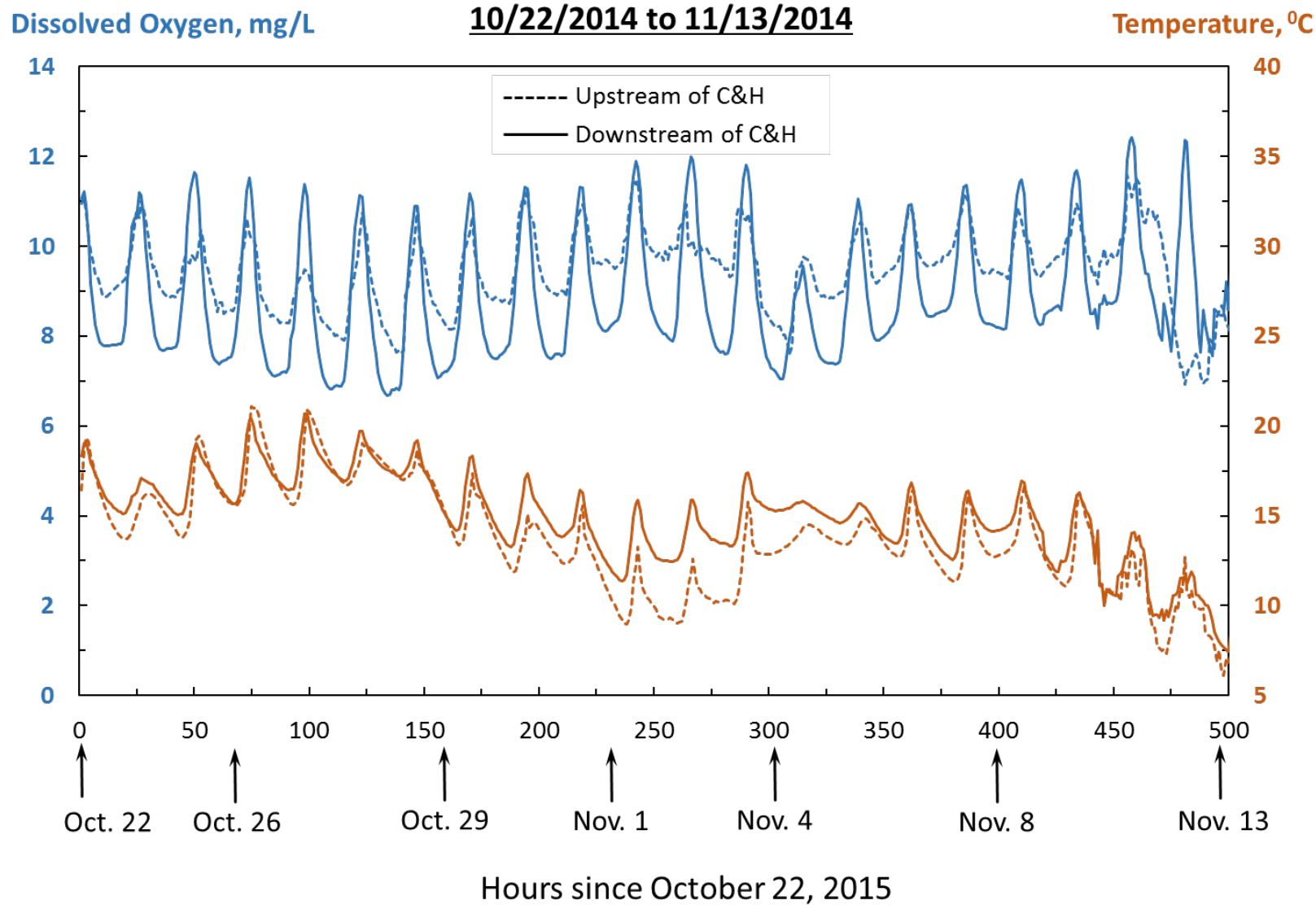

Figure 8. Water temperature and dissolved oxygen concentration upstream and downstream of the C&H Farm between October 22 and November 13, 2014.

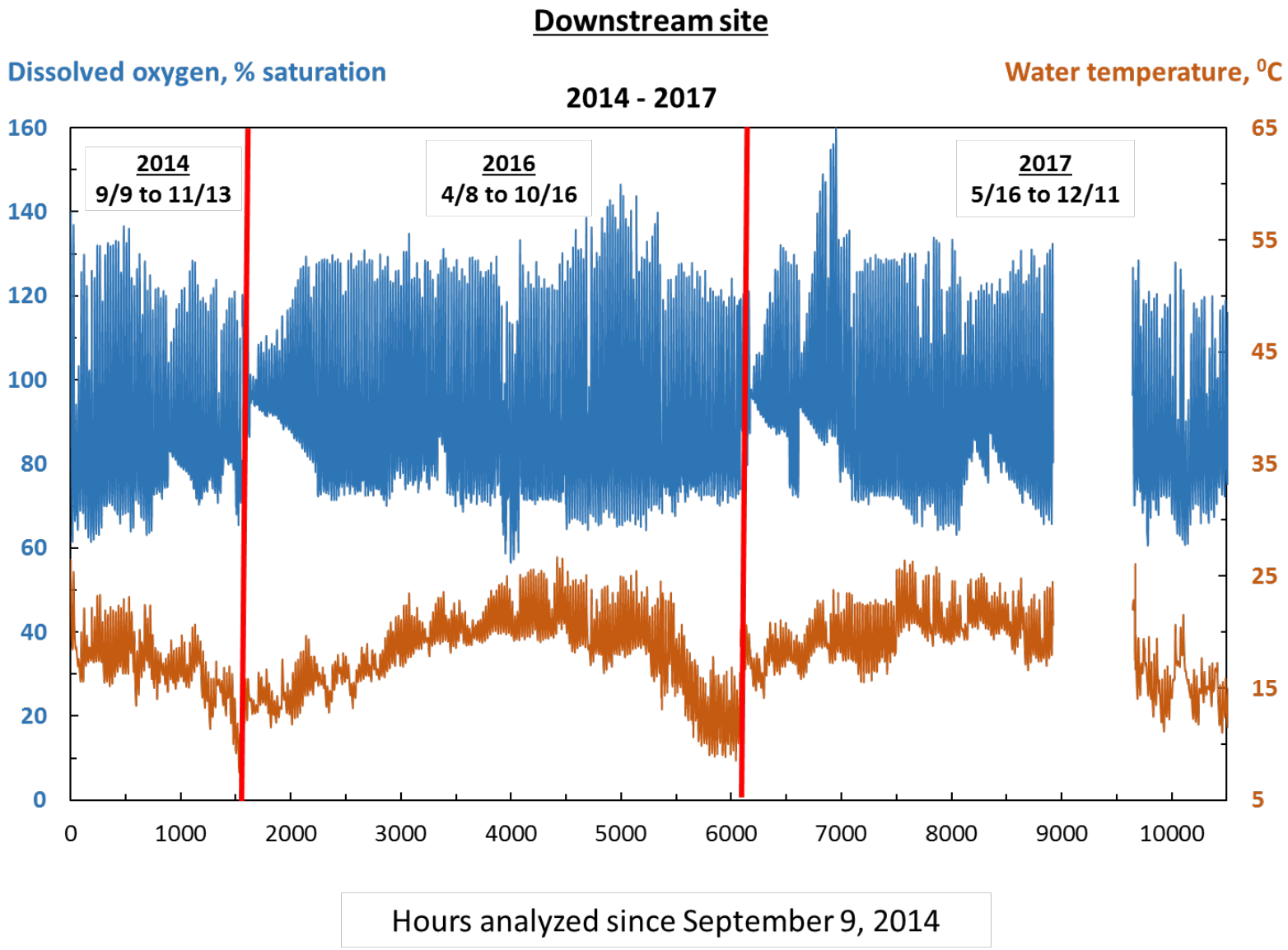

Figure 9. Water temperature and dissolved oxygen saturation downstream of the C&H Farm between September 9 and December 11, 2017.

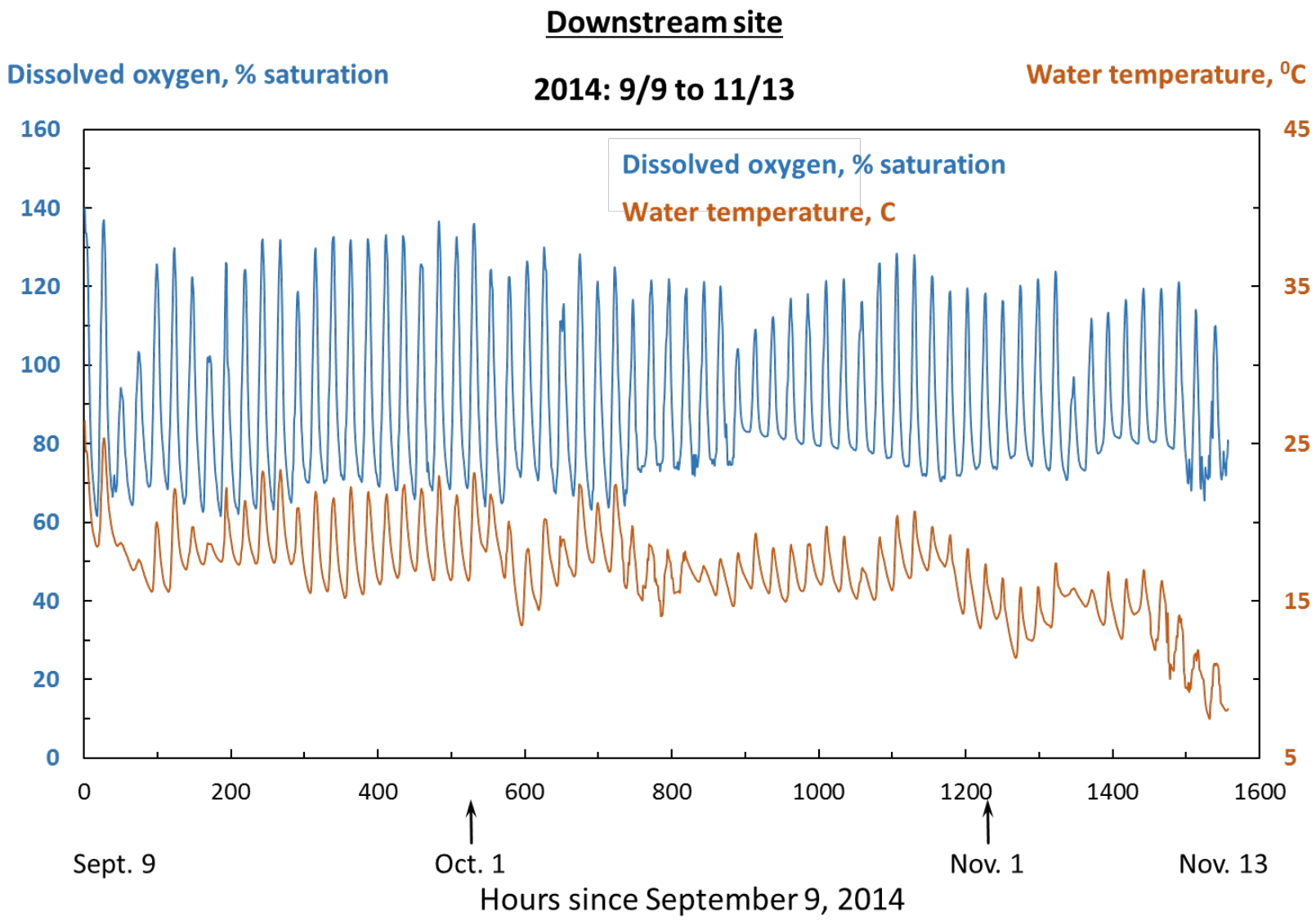

Figure 10. Water temperature and dissolved oxygen saturation downstream of the C&H Farm between September 9 and November 13, 2014.

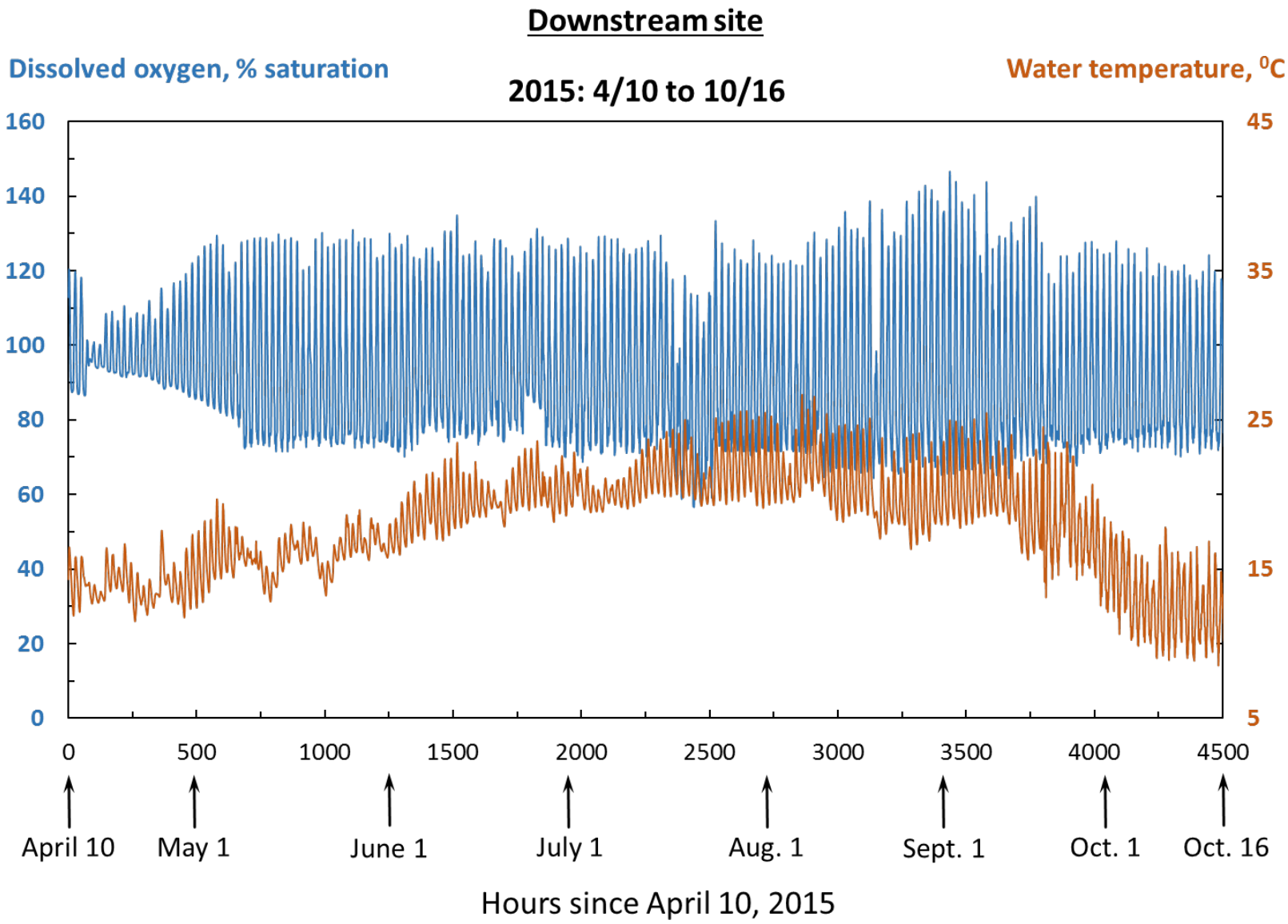

Figure 11. Water temperature and dissolved oxygen saturation downstream of the C&H Farm between April 10 and October 16, 2015.

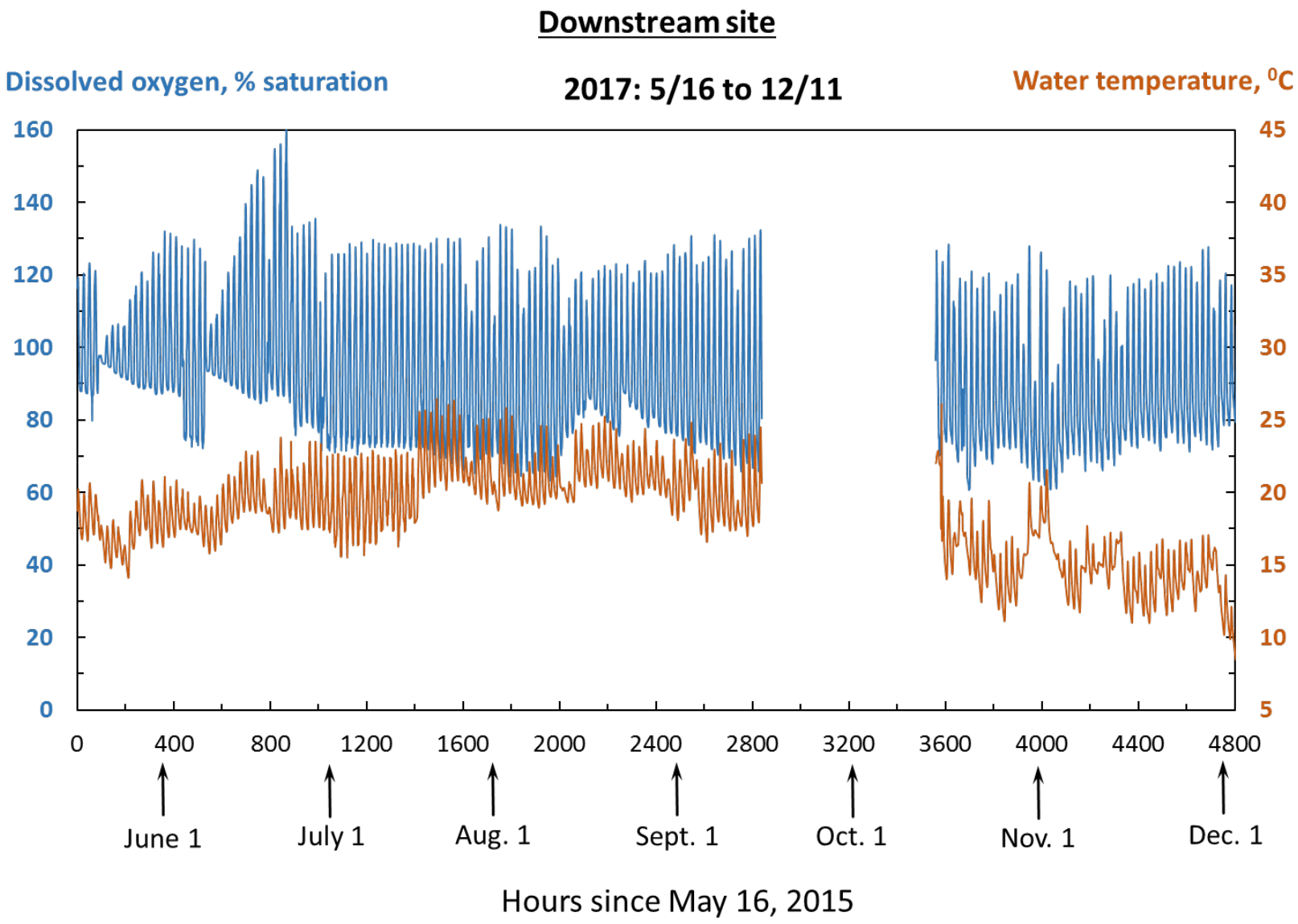

Figure 12. Water temperature and dissolved oxygen saturation downstream of the C&H Farm between May 15 and December 11, 2017.

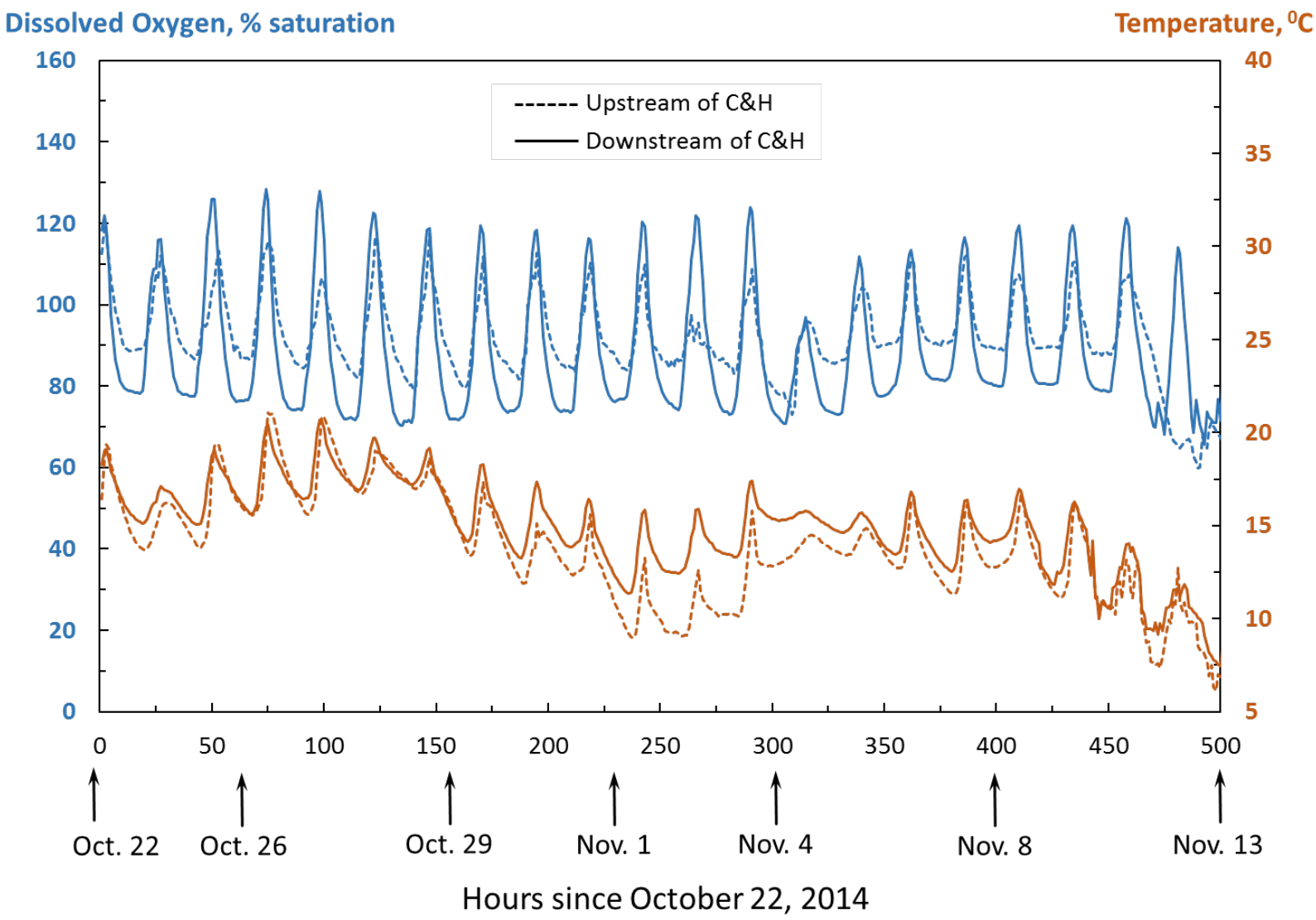

Figure 13. Water temperature and dissolved oxygen saturation upstream and downstream of the C&H Farm between October 22 and November 13, 2014.

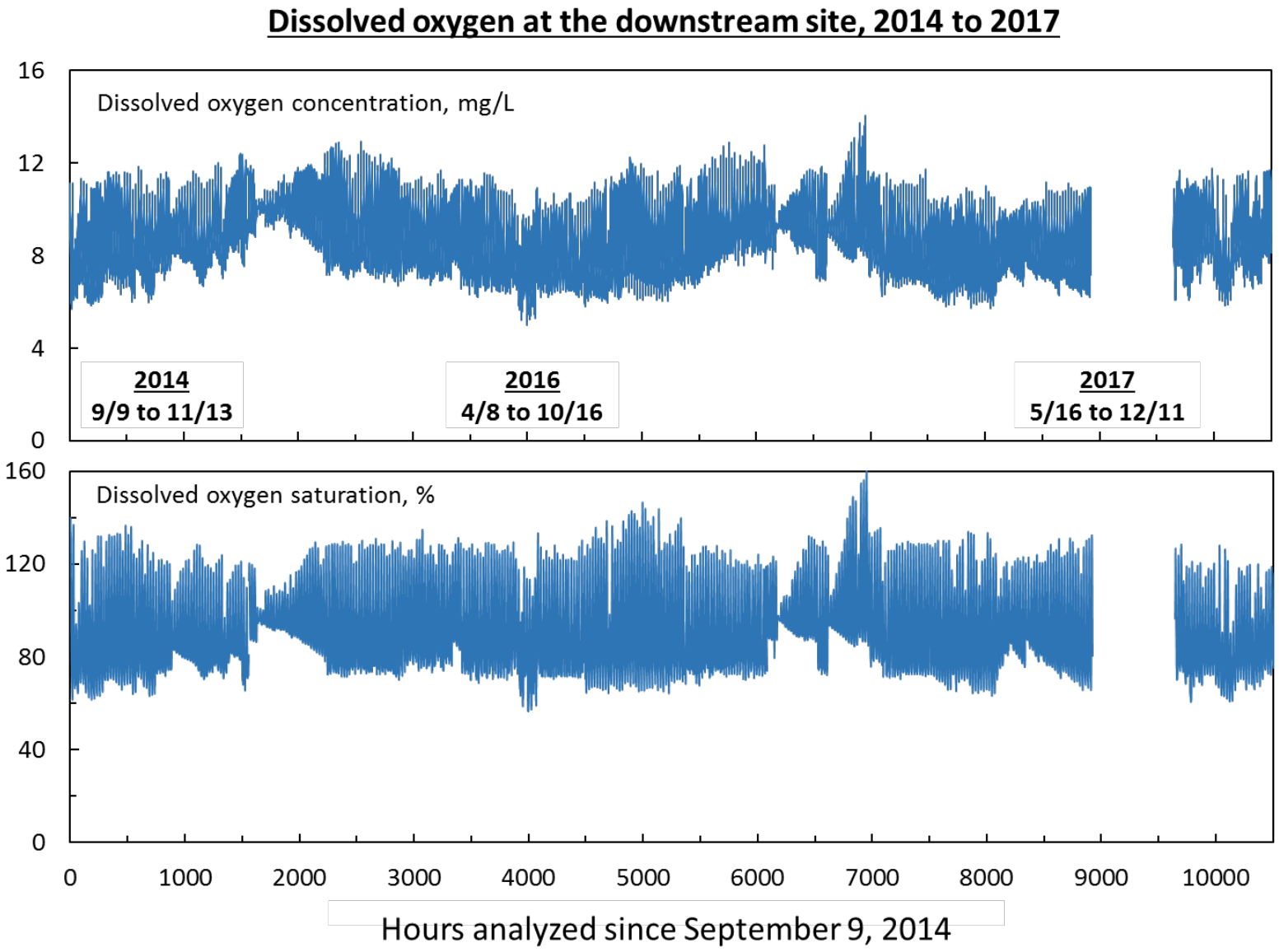

Figure 14. Dissolved oxygen concentration and % saturation downstream of the C&H Farm between 2014 and 2017.

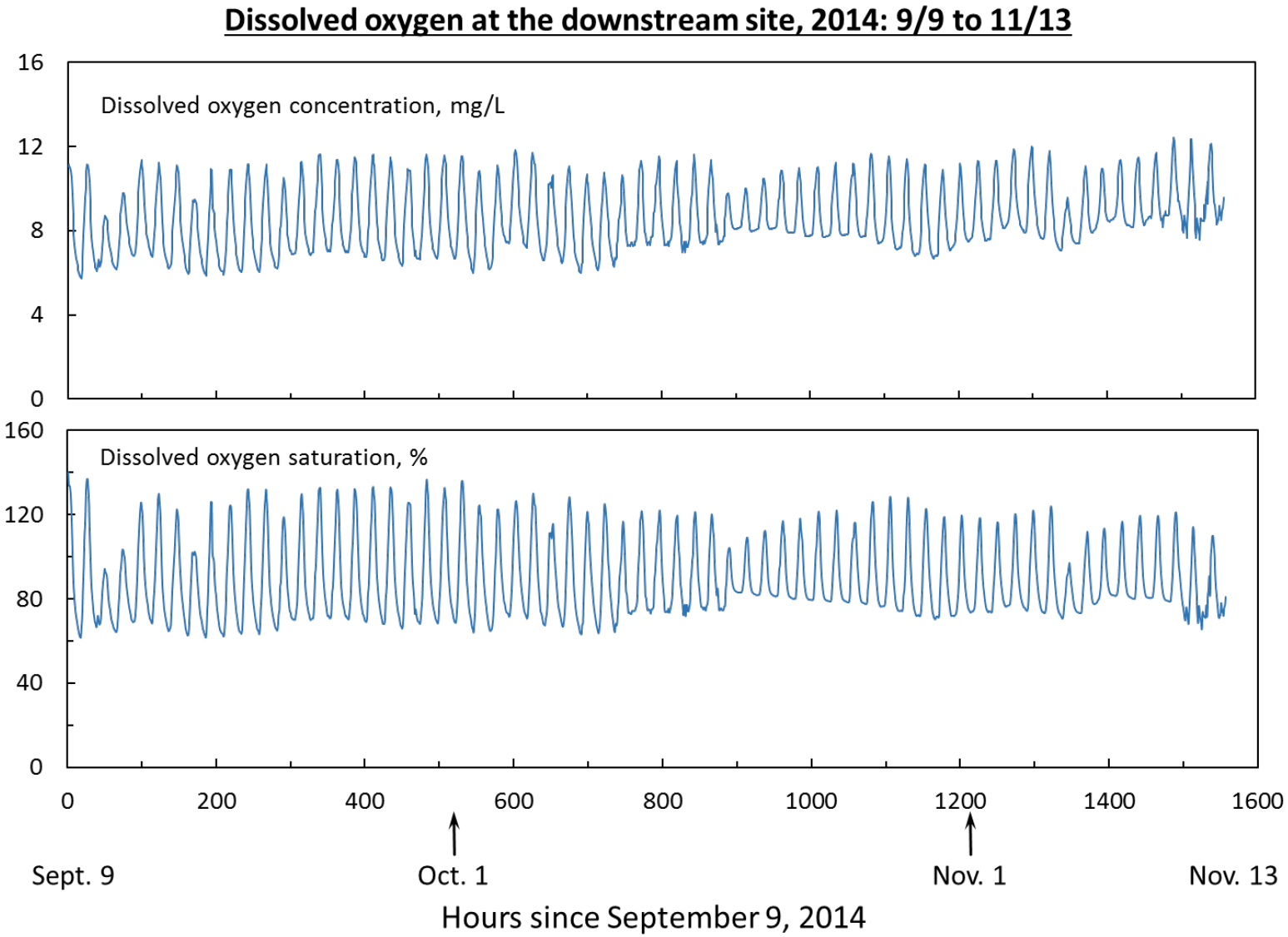

Figure 15. Dissolved oxygen concentration and % saturation downstream of the C&H Farm between September 9 and November 13, 2014.

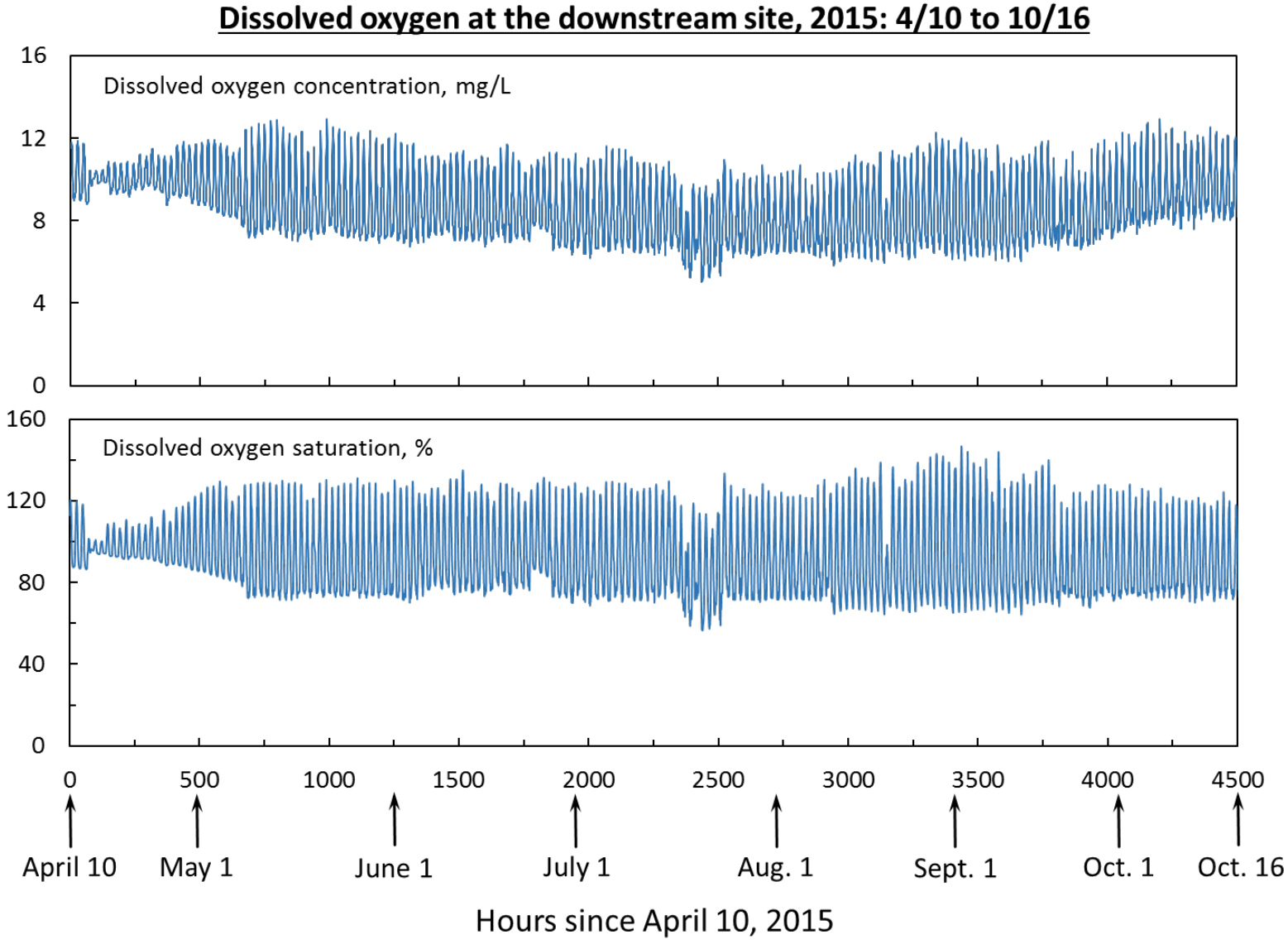

Figure 16. Dissolved oxygen concentration and % saturation downstream of the C&H Farm between April 10 and October 16, 2015

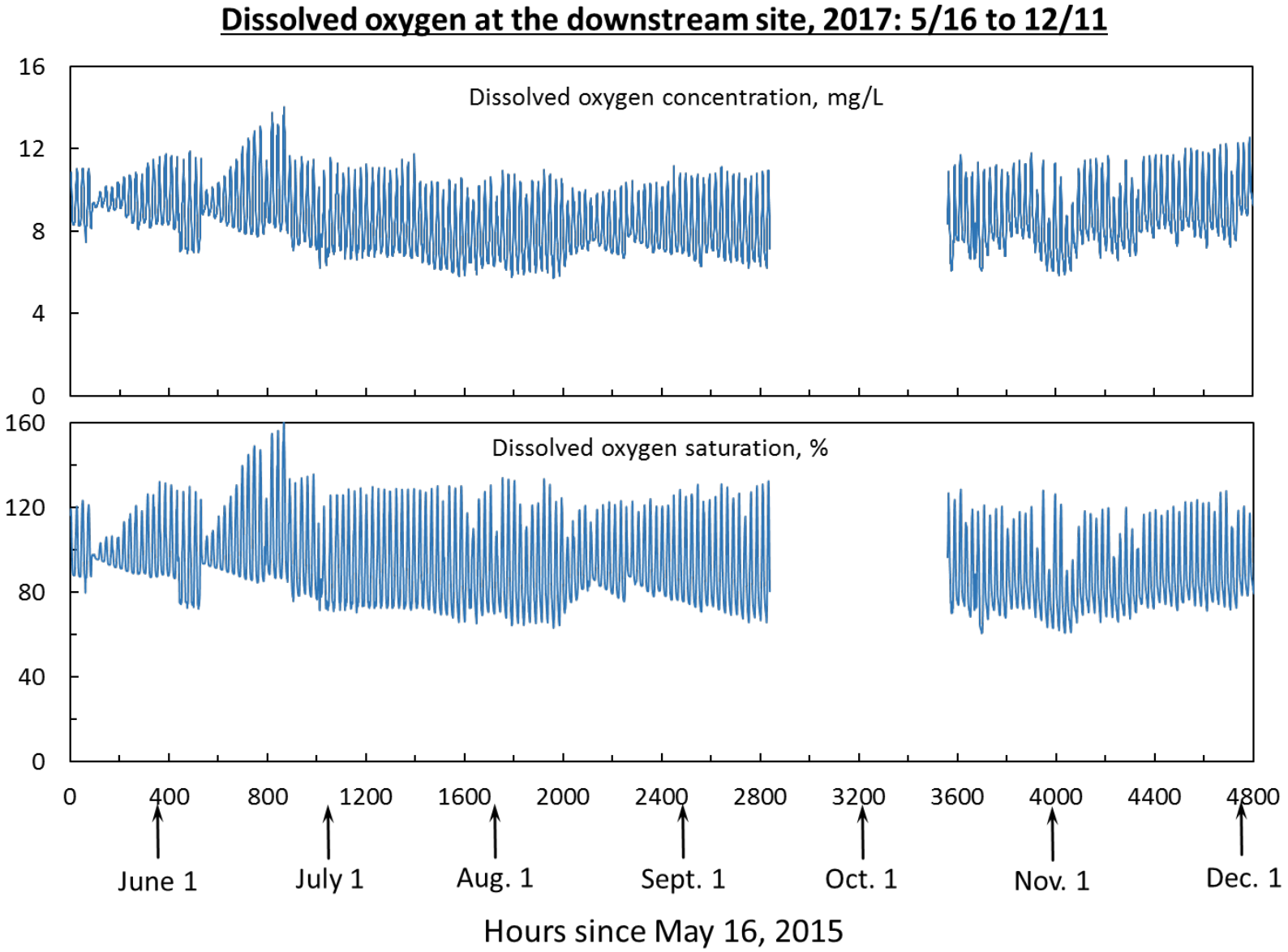

Figure 17. Dissolved oxygen concentration and % saturation downstream of the C&H Farm between May 16 and December 11, 2017.

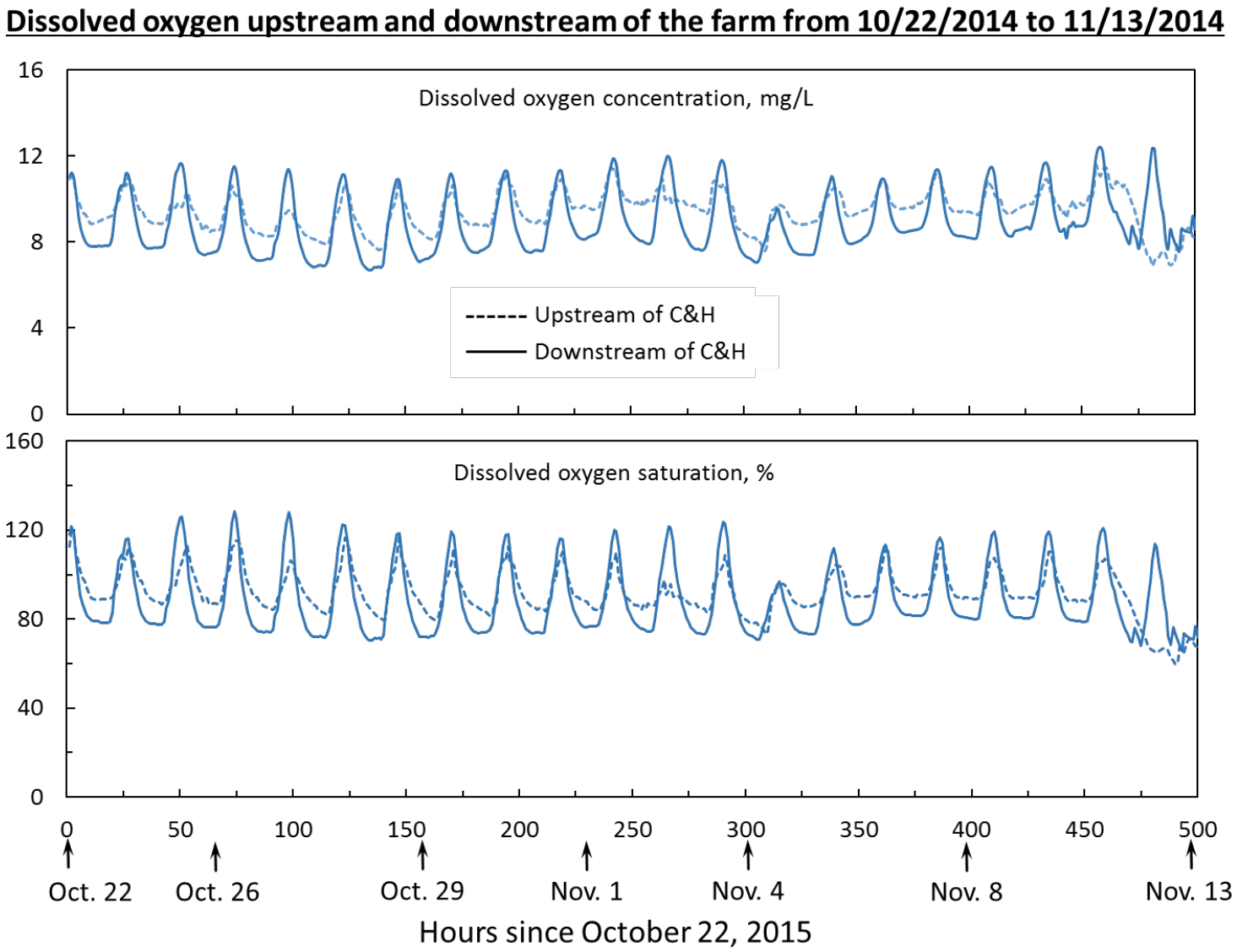

Figure 18. Dissolved oxygen concentration and % saturation upstream and downstream of the C&H Farm between October 22, 2014 and November 13, 2014.

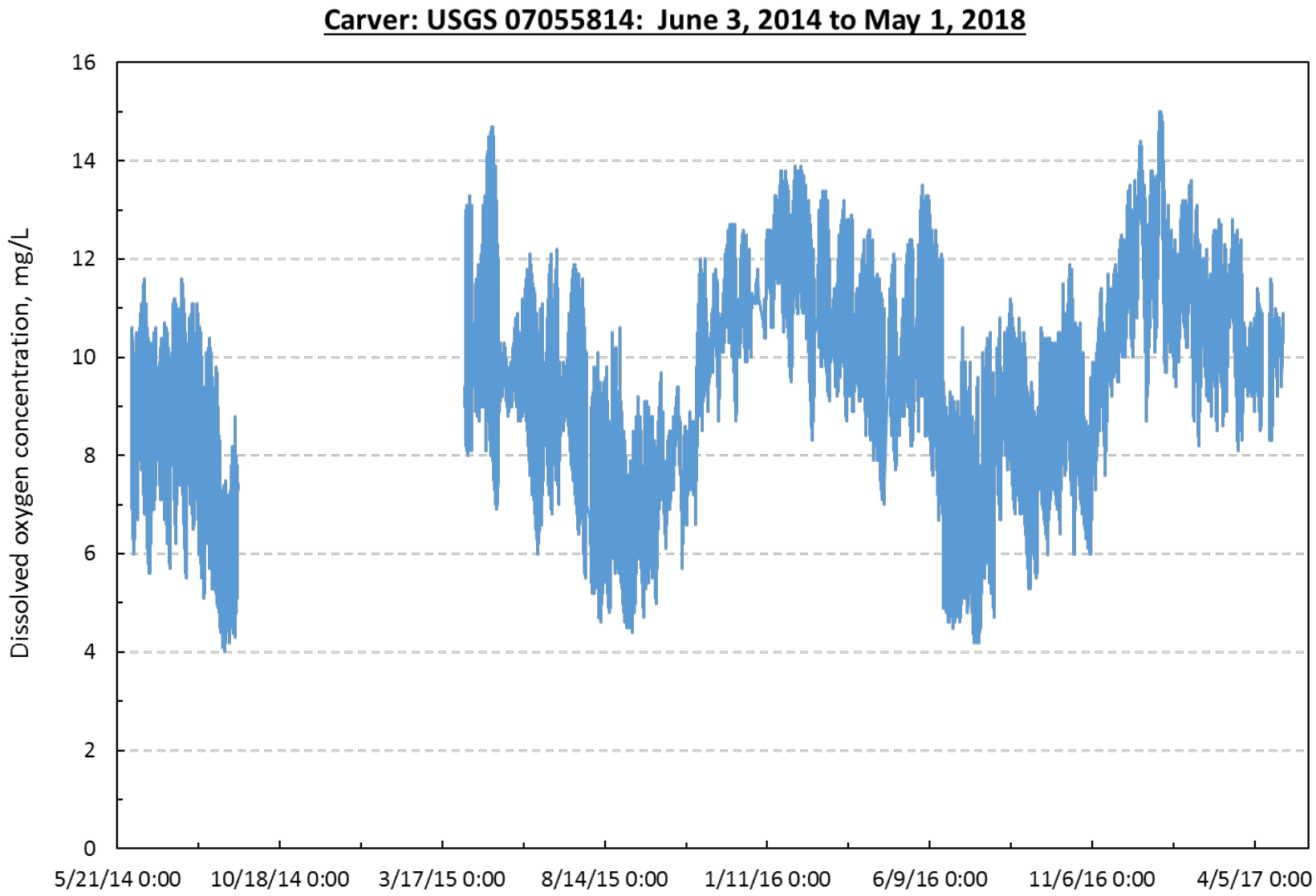

Figure 19. Dissolved oxygen concentration at the USGS Carver site (USGA: 07055814) for June 3 to May 1, 2018.