

Protecting Our Water Environment



Metropolitan Water Reclamation District of Greater Chicago

***MONITORING AND RESEARCH
DEPARTMENT***

REPORT NO. 20-27

***CONTINUOUS DISSOLVED OXYGEN MONITORING IN THE SERVICE
AREA OF THE METROPOLITAN WATER RECLAMATION DISTRICT OF
GREATER CHICAGO DURING 2019***

October 2020

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**CONTINUOUS DISSOLVED OXYGEN MONITORING IN THE SERVICE AREA OF
THE METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER
CHICAGO DURING 2019**

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LIST OF ABBREVIATIONS

CAWS	Chicago Area Waterway System
CDOM	Continuous Dissolved Oxygen Monitoring
COV	coefficient of variation
CRS	Chicago River System
CSC	Calumet-Sag Channel
CSSC	Chicago Sanitary and Ship Canal
District	Metropolitan Water Reclamation District of Greater Chicago
DO	dissolved oxygen
Eureka	Eureka Water Probes
IPCB	Illinois Pollution Control Board
L	liter
LCR	Little Calumet River
M&R	Monitoring and Research
mg	milligram
NBCR	North Branch Chicago River
NSC	North Shore Channel
PVC	polyvinyl chloride
QAPP	Quality Assurance Project Plan
SBCR	South Branch Chicago River
WRPs	Water Reclamation Plants
YSI	YSI Incorporated

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DISCLAIMER

Mention of proprietary equipment and chemicals in this report does not constitute endorsement by the Metropolitan Water Reclamation District of Greater Chicago.

INTRODUCTION

The Chicago Area Waterway System (CAWS) consists of 78 miles of canals within an approximately 740-square-mile watershed, which serves the Chicago area for two principal purposes: (1) the drainage of urban stormwater runoff and treated municipal wastewater effluent, and (2) the support of commercial navigation. Approximately 75 percent of the length is composed of man-made canals, and the remainder is composed of natural streams that have been deepened, straightened, and/or widened to such an extent that reversion to the natural state is not practical. The flow of water in the CAWS is artificially controlled by hydraulic structures, and over 70 percent of the annual flow is from the discharge of treated municipal wastewater effluents (Metropolitan Water Reclamation District of Greater Chicago [District], 2008). The CAWS has two river systems: the Calumet River System and the Chicago River System (CRS).

A third river system that traverses the Chicago area is the Upper Des Plaines River System. This system provides drainage for approximately 700 square miles and originates in the state of Wisconsin. The portion of the Des Plaines River within the District's jurisdiction flows southward from Lake Cook Road through western Cook County. One of its larger tributaries, Salt Creek, flows through western Cook and eastern DuPage Counties and meets the Des Plaines River in the town of Lyons. The system is composed of more natural streams when compared to the CAWS, but also receives stormwater runoff and treated wastewater. The entire Des Plaines River Watershed has been impacted by suburban sprawl with over six million people residing within it and having 58.7 percent of land use comprised as urban development, and 33.2 percent as agriculture (Illinois Department of Natural Resources, 2018)

In 1998, the Monitoring and Research Department initiated a comprehensive field-monitoring program in order to locate and identify reaches in the CRS where the dissolved oxygen (DO) concentrations were below the applicable Illinois Pollution Control Board (IPCB) DO standard. Initially, the program was intended to focus on the CRS for a two-year period, but the duration of the monitoring program was extended and the scope was expanded to include the Calumet River System in 2001, and the Chicago metropolitan area wadeable streams in 2005. The program is referred to as the District's Continuous Dissolved Oxygen Monitoring (CDOM) Program. The CDOM Program was conducted under the guidance of a Quality Assurance Project Plan (QAPP) which is available on the District website (www.mwrd.org). Currently, continuous DO monitoring in the CRS and Calumet River System is required in National Pollutant Discharge Elimination System permits for the Terrence J. O'Brien and Calumet Water Reclamation Plants (WRPs), and data is submitted to the Illinois Environmental Protection Agency quarterly. The data are used to characterize the DO behavior in waterway systems receiving District WRP effluents.

This report summarizes the monitoring results for the period January 1 through December 31, 2019, for the deep-draft waterways and wadeable streams within the Chicago Metropolitan area.

MONITORING LOCATIONS AND APPLICABLE DISSOLVED OXYGEN STANDARDS

Locations and Descriptions

The CDOM Program supplies the District with water quality data throughout the year for both the wadeable and deep-draft waterways within its jurisdiction. All of the 2019 CDOM stations are shown in [Figure 1](#). Descriptions of the locations for the deep-draft and wadeable monitoring stations are listed in [Table 1](#).

There were 16 deep-draft CDOM monitoring stations in the CAWS. The deep-draft monitoring stations included two locations in the North Shore Channel (NSC), two locations in the North Branch Chicago River (NBCR), two locations in the Chicago River, one location in the South Branch Chicago River (SBCR), two locations in Bubbly Creek, three locations in the Chicago Sanitary and Ship Canal (CSSC), two locations in the Little Calumet River (LCR), and two locations in the Calumet-Sag Channel (CSC).

There were five CDOM stations in the Chicago Metropolitan Area Wadeable Streams. Four wadeable monitoring stations were located in the Upper Des Plaines River System. Two stations were on the Upper Des Plaines River and two stations were on Salt Creek. One wadeable monitoring station was in the Calumet River System on the LCR.

The CDOM station on the Chicago River at Clark Street was discontinued and replaced by the station at Michigan Avenue on the main stem of the Chicago River in early June 2019 due to deteriorating infrastructure.

Designated Uses

The IPCB has assigned water uses for water bodies within the state of Illinois. The Chicago River, Salt Creek, Des Plaines River, and the shallow portion of the LCR are designated as General Use Waters. The NSC, NBCR, SBCR, Grand Calumet River, the deep-draft portion of the LCR, and the CSC are designated as CAWS Aquatic Life Use A Waters. The CSSC is designated as CAWS and Brandon Pool Aquatic Life Use B Waters.

Dissolved Oxygen Water Quality Standards

The IPCB has established water quality standards for DO. In Bubbly Creek, the DO shall not be less than 4.0 milligrams per liter (mg/L) at any time. For the CAWS Aquatic Life Use A Waters, the DO shall not be less than 3.5 mg/L at any time and meet a 4.0 mg/L daily minimum averaged over seven days from August through February, and the DO shall not be below 5.0 mg/L at any time from March through July. For the CAWS and Brandon Pool Aquatic Life Use B Waters, the DO shall not be less than 3.5 mg/L at any time and meet a 4.0 mg/L daily minimum averaged over seven days. In General Use Waters, the DO shall not be less than 3.5 mg/L at any time and shall meet a 4.0 mg/L daily minimum averaged over seven days, and shall meet a 5.5 mg/L daily mean averaged over 30 days from August through February; and the DO shall not be less than 5.0 mg/L at any time and shall meet a 6.0 mg/L daily mean averaged over seven days from March through July.

FIGURE 1: 2019 CONTINUOUS DISSOLVED OXYGEN MONITORING STATIONS

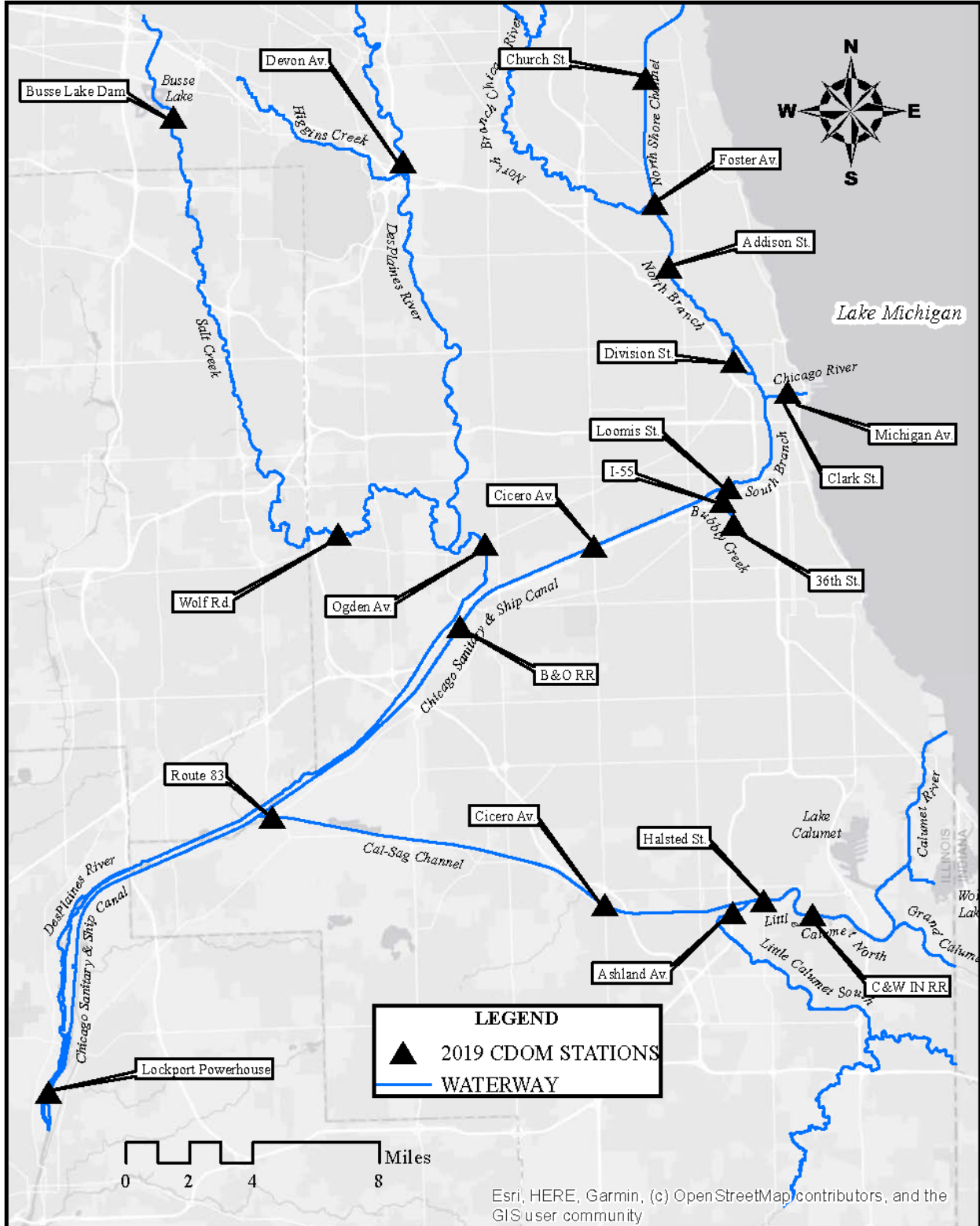


TABLE 1: CONTINUOUS DISSOLVED OXYGEN MONITORING STATIONS
DURING 2019

Monitoring Station	Waterway	Description of Monitoring Station
-----Chicago River System-----		
Church Street	North Shore Channel	1.8 miles above O'Brien WRP outfall, 2.4 miles below Wilmette Pumping Station, monitor on southwest side Church Street bridge, 1 foot below water surface.
Foster Avenue	North Shore Channel	3.2 miles below O'Brien WRP outfall, 1.5 miles below Devon Aeration Station, 0.1 mile above junction with North Branch Chicago River, monitor on northwest side Foster Avenue bridge, 3 feet below water surface.
Addison Street	North Branch Chicago River	5.2 miles below O'Brien WRP outfall, monitor on northwest side Addison Street bridge, 3 feet below water surface.
Division Street	North Branch Chicago River	8.8 miles below O'Brien WRP outfall; 1.4 miles below Webster Aeration Station; monitor on northeast side Division Street bridge, 3 feet below water surface.
Michigan Avenue	Chicago River	0.8 miles below Chicago River Controlling Works; 0.8 miles above junction with South Branch Chicago River; water quality monitor on northeast side Michigan Avenue bridge, 3 feet below water surface.
Clark Street	Chicago River	1.2 miles below Chicago River Controlling Works, 0.4 mile above junction with South Branch Chicago River, monitor on northeast side Clark Street bridge, 3 feet below water surface.

TABLE 1 (Continued): CONTINUOUS DISSOLVED OXYGEN MONITORING STATIONS DURING 2019

Monitoring Station	Waterway	Description of Monitoring Station
-----Chicago River System (Continued)-----		
Loomis Street	South Branch Chicago River	3.6 miles below junction with Chicago River, monitor on northeast side Loomis Street bridge, 3 feet below water surface.
36th Street	Bubbly Creek	0.2 mile below Racine Avenue Pumping Station, 1.2 miles above junction with South Branch of the Chicago River, monitor attached to concrete wall on west side of river, 3 feet below water surface.
Interstate Highway 55	Bubbly Creek	1.0 mile below Racine Avenue Pumping Station, 0.4 mile above junction with South Branch of the Chicago River, monitor on northwest side I-55 bridge, 3 feet below water surface.
Cicero Avenue	Chicago Sanitary and Ship Canal	1.5 miles above Stickney WRP outfall, monitor on northeast side Cicero Avenue bridge, 3 feet below water.
B&O Central Railroad	Chicago Sanitary and Ship Canal	3.6 miles below Stickney WRP outfall, monitor in center of canal, east side B&O Central RR ¹ bridge, 3 feet below water surface.
Lockport Powerhouse	Chicago Sanitary and Ship Canal	0.1 mile above Lockport Powerhouse, 1.1 miles above junction with Des Plaines River, monitor on north side of canal, in forebay area on fender wall, 3 feet below water surface.

TABLE 1 (Continued): CONTINUOUS DISSOLVED OXYGEN MONITORING STATIONS DURING 2019

Monitoring Station	Waterway	Description of Monitoring Station
-----Calumet River System-----		
C&W Indiana Railroad	Little Calumet River	5.2 miles below SEPA ² 1, 1.5 miles above SEPA 2, 3.6 miles below Thomas J. O'Brien Lock and Dam, 1.3 miles above Calumet WRP outfall, monitor attached to northeast side C&W Indiana RR bridge, 3 feet below water surface.
Halsted Street	Little Calumet River	7.7 miles below SEPA 1, 1.0 mile below SEPA 2, 1.2 miles below Calumet WRP, 0.5 mile above junction with Calumet-Sag Channel, monitor attached to southeast side Halsted Street bridge, 3 feet below water surface.
Ashland Avenue	Little Calumet River	0.5 mile above junction with Calumet-Sag Channel, monitor attached to east side of Ashland Avenue bridge, 1 foot from streambed.
Cicero Avenue	Calumet-Sag Channel	3.1 miles below SEPA 3, 3.3 miles above SEPA 4, monitor attached to northwest side Cicero Avenue bridge, 3 feet below water surface.
Route 83	Calumet-Sag Channel	0.4 mile above junction with Chicago Sanitary and Ship Canal, 0.3 mile above Canal Junction SEPA Station, monitor on southwest side Illinois Central-Gulf RR bridge, 3 feet below water surface.
-----Des Plaines River System-----		
Devon Avenue	Des Plaines River	0.7 mile above junction with Willow Creek, monitor on northwest side of Devon Avenue bridge, 2-4 inches from stream bed.

TABLE 1 (Continued): CONTINUOUS DISSOLVED OXYGEN MONITORING STATIONS DURING 2019

Monitoring Station	Waterway	Description of Monitoring Station
-----Des Plaines River System (Continued)-----		
Ogden Avenue	Des Plaines River	1.7 miles below junction with Salt Creek, 25.8 miles above junction with Chicago Sanitary and Ship Canal, monitor on center of south side of Ogden Avenue bridge, 2–4 inches from stream bed.
Busse Lake Dam	Salt Creek	0.1 mile above Egan WRP outfall, water quality monitor on bike path bridge support, downstream of Busse Woods South Dam, in center of creek, 2–4 inches from stream bed.
Wolf Road	Salt Creek	8.0 miles above junction with Des Plaines River, water quality monitor on northwest side of Wolf Road bridge, 2–4 inches from stream bed.

¹RR=Railroad.

²SEPA=Sidestream Elevated Pool Aeration Station.

MATERIALS AND METHODS

Water Quality Monitors

The continuous water quality monitors (monitors) used to collect these data are manufactured by YSI Incorporated (YSI) of Yellow Springs, Ohio, and Eureka Water Probes (Eureka) of Austin, Texas. The DO was measured hourly using a YSI Model 6920 or 6600 monitor or a Eureka Manta2™ or Manta+™ multiprobe. In order to protect the monitors from marine navigation and vandalism, the monitors were deployed in the field in stainless steel or polyvinyl chloride (PVC) housings. A fixed length of 8-inch diameter stainless steel or PVC pipe is mounted on a bridge abutment with multiple 2-inch circular openings on the submerged end to allow sufficient flow of water through the pipe and an access hatch on the top end to allow for the exchange of monitors.

District personnel retrieved each monitor from the field following 21 days of continuous monitoring. Prior to retrieval, a measurement of the DO was taken next to the protective housing using a DO meter to compare with the monitor results. An additional monitor that had been previously calibrated and serviced in the laboratory was then deployed to replace the retrieved monitor. The retrieved monitors were returned to the laboratory for data downloading, exterior cleaning, servicing, and a calibration check of the DO sensors. The monitors were temporarily stored in holding tanks containing tap water for subsequent deployment during the following week.

Data Management and Review

Hourly DO data were directly exported electronically from individual monitors to a specially designed Microsoft® SQL Server 2014 database for data processing and storage. All DO data were carefully reviewed for accuracy following the QAPP. The review process included the following:

1. Conducting a post-deployment calibration check to 100 percent DO saturation by a monitor after retrieval from the field (DO rejection criteria = difference greater than 0.4 mg/L).
2. Comparing the last hourly DO concentration measured by the monitor retrieved in the field to the DO concentration measured with a DO meter taken at the time of retrieval (DO rejection criteria = relative percent difference greater than 20 percent and an absolute magnitude greater than 0.3 mg/L).

Criterion 1 would entail rejection of all hourly readings during the deployment period and criterion 2 could result in the rejection of all readings after a careful review of the data. If evidence suggests that there were waterway conditions at the time of the DO meter measurement that explain a difference greater than 20 percent, the data may be accepted. If an operator error occurred such as the monitor being deployed with low battery power or deployed without the sampling mode turned on, all of the readings during the deployment period would be rejected.

A comprehensive description of methods is presented in Revision 2.1 of the CDOM Program QAPP, effective July 1, 2016.

Cross-Sectional Surveys

During the spring, summer, and fall of 2019, cross-sectional DO surveys were conducted in the CRS, Calumet River System, and Des Plaines River System to determine if the fixed continuous monitoring locations represented the DO concentrations across the waterway. The DO concentrations were measured directly with a monitor at multiple locations and depths across the waterway. The cross-sectional DO measurements were taken in the center of the waterway and at the right and left sides of the flow from a bridge, catwalk, or boat. DO measurements were recorded at up to four depths for each location, including just above the bottom of the stream bed, one-half the total depth, three feet below the surface, and at the surface. If the overall depth was less than eight feet, then the one-half depth measurement was not recorded. If the overall depth was less than four feet, only bottom and surface measurements were recorded, and if the overall depth was less than one foot, only a surface measurement was recorded.

RESULTS

The annual minimum, maximum, and mean DO concentrations measured at all 21 stations during 2019 are shown in [Table 2](#).

The number and percent of measured DO concentrations rejected and removed from the Microsoft® SQL Server 2014 database following review during 2019 are summarized in [Table 3](#). The deployment period and reason for the data rejection are presented as a footnote.

The percent distribution of DO concentrations in 1 mg/L increments from <1.0 mg/L to >10.0 mg/L at the 21 monitoring stations during 2019 are presented in [Table 4](#).

Individual graphs showing hourly DO concentrations at each monitoring station are presented in [Figures 2](#) through [22](#).

Summary statistics for DO measured during cross-sectional surveys are shown in [Appendix A](#). The results from the surveys show that for most of the monitoring locations the variation in cross-section measured DO is minimal (coefficient of variation [COV] <10 percent). At a few locations, the COV was greater than or near 10 percent. The cross-sectional DO variations for these surveys are described below:

- At 36th Street and Interstate Highway 55 (I-55) in Bubbly Creek, the 2019 cross-sectional surveys conducted in May and August had a COV greater than 10 percent. The measured DOs for 36th Street are shown in [Figure 23](#) and the measured DOs for I-55 are shown in [Figure 24](#). This measured variability in cross-sectional DO suggests that the reported DO for 36th Street and I-55 may not be representative of the entire waterway in the spring or summer.
- At Cicero Avenue in the CSSC, the 2019 cross-sectional survey on August 21, 2019, had a COV of 16.71 percent. The measured DOs are shown in [Figure 25](#). The data presented in [Figure 25](#) suggests that the data variability was mainly caused by a very low DO measurement at the bottom location in the center, possibly due to the sediment oxygen demand. Therefore, the reported DO by the monitor for Cicero Avenue may not be representative for that particular area (center bottom), but representative for other areas in the cross section in the summer.
- At Ogden Avenue in the Des Plaines River, the 2019 cross-sectional survey on May 16, 2019, had a COV of 13.11 percent. The measured DOs are shown in [Figure 26](#). This measured variability in cross-sectional DO suggests that the reported DO for Ogden Avenue may not be representative of the entire waterway in the spring.

TABLE 2: MINIMUM, MAXIMUM, AND MEAN HOURLY DISSOLVED OXYGEN CONCENTRATIONS DURING 2019

Monitoring Station	Waterway	DO Concentration (mg/L)		
		Minimum	Maximum	Mean
-----Chicago River System-----				
Church Street	North Shore Channel	3.5	19.3	9.8
Foster Avenue	North Shore Channel	4.6	11.2	8.4
Addison Street	North Branch Chicago River	2.4	12.8	8.4
Division Street	North Branch Chicago River	2.6	12.4	7.6
Michigan Avenue	Chicago River	6.7	12.6	10.0
Clark Street	Chicago River	5.1	14.1	10.5
Loomis Street	South Branch Chicago River	2.5	12.0	7.6
36 th Street	Bubbly Creek	0.0	35.4	8.0
Interstate Highway 55	Bubbly Creek	0.0	20.3	6.5
Cicero Avenue	Chicago Sanitary and Ship Canal	0.0	11.7	7.4
B&O Central Railroad	Chicago Sanitary and Ship Canal	0.0	9.6	6.9
Lockport Powerhouse	Chicago Sanitary and Ship Canal	0.2	10.7	6.4
-----Calumet River System-----				
C&W Indiana Railroad	Little Calumet River	1.1	14.0	9.2
Halsted Street	Little Calumet River	1.2	13.6	8.0
Ashland Avenue	Little Calumet River	0.4	16.7	8.8
Cicero Avenue	Calumet-Sag Channel	3.8	11.4	7.7
Route 83	Calumet-Sag Channel	2.4	13.3	7.6
-----Des Plaines River System-----				
Devon Avenue	Des Plaines River	4.0	15.7	9.7
Ogden Avenue	Des Plaines River	1.6	16.0	9.6
Busse Lake Dam	Salt Creek	0.0	15.6	10.3
Wolf Road	Salt Creek	4.2	17.6	9.8

TABLE 3: NUMBER AND PERCENT OF DISSOLVED OXYGEN VALUES NOT MEETING ACCEPTANCE CRITERIA DURING 2019

Monitoring Station	Waterway	Number of DO Values Rejected	Percent of DO Values Rejected
Church Street	North Shore Channel	48	<1 ^a
Foster Avenue	North Shore Channel	0	0
Addison Street	North Branch Chicago River	1,009	12 ^b
Division Street	North Branch Chicago River	2,000	23 ^c
Michigan Avenue	Chicago River	1,343	15 ^d
Clark Street	Chicago River	0	0
Loomis Street	South Branch Chicago River	647	7 ^e
36 th Street	Bubbly Creek	24	<1 ^f
Interstate Highway 55	Bubbly Creek	0	0
Cicero Avenue	Chicago Sanitary and Ship Canal	503	6 ^g
B&O Central Railroad	Chicago Sanitary and Ship Canal	649	7 ^h
Lockport Powerhouse	Chicago Sanitary and Ship Canal	830	9 ⁱ
C&W Indiana Railroad	Little Calumet River	11	<1 ^j
Halsted Street	Little Calumet River	959	11 ^k
Ashland Avenue	Little Calumet River	3	<1 ^l
Cicero Avenue	Calumet-Sag Channel	2,630	30 ^m
Route 83	Calumet-Sag Channel	2	<1 ⁿ
Devon Avenue	Des Plaines River	1,416	16 ^o
Ogden Avenue	Des Plaines River	667	8 ^p
Busse Lake Dam	Salt Creek	385	4 ^q
Wolf Road	Salt Creek	669	8 ^r

^a8/29–8/30/19: equipment failure.

^b5/22–6/12/19: monitor failed criterion 2; 9/4–9/25/19: operator error.

^c4/10–5/7/19, 5/22–6/12/19: monitor failed criterion 2; 7/18, 11/5–11/26/19: equipment failure; 12/17–12/31/19: monitor failed criterion 2.

^d6/27/19, 8/22/19, 12/17–12/31/19: equipment failure.

^e1/18–2/14/19, 4/26/19, 7/23/19: equipment failure.

^f2/2/19, 6/12–6/24/19: equipment failure.

^g5/8–5/29/19: operator error.

^h1/18–2/14/19: equipment failure.

ⁱ6/11–7/2/19, 8/23/19, 10/18/19, 12/18–12/31/19: equipment failure.

^j8/4/19, 8/5/19, 8/6/19: equipment failure.

^k3/29/19, 3/30/19, 3/31/19, 4/1/19, 9/18–10/9/19: equipment failure; 12/13–12/31/19: monitor failed criterion 2.

^l4/2/19, 5/12/19, 6/28/19: equipment failure

^m1/23–2/20/19, 6/5–6/26/19: equipment failure; 6/26–8/7/19, 12/13–12/31/19: monitor failed criterion 2.

ⁿ7/12/19, 12/13/19: equipment failure

^o5/14–5/30/19, 10/22–12/4/19: equipment failure.

^p4/16–5/14/19: monitor failed criterion 1.

^q5/14–5/30/19: monitor failed criterion 2.

^r4/16–5/14/19: equipment failure.

TABLE 4: PERCENT OF DISSOLVED OXYGEN VALUES IN SELECTED RANGES DURING 2019

Monitoring Station	Waterway	Percent of Dissolved Oxygen Values in Range (mg/L) ^a										
		<1	1-<2	2-<3	3-<4	4-<5	5-<6	6-<7	7-<8	8-<9	9-<10	>10
-----Chicago River System-----												
Church Street	North Shore Channel	0	0	0	0	<1	<1	5	14	23	18	40
Foster Avenue	North Shore Channel	0	0	0	0	0	2	7	25	40	23	4
Addison Street	North Branch Chicago River	0	0	0	0	1	6	12	22	23	21	15
Division Street	North Branch Chicago River	0	0	<1	1	3	11	31	17	14	16	9
Michigan Avenue	Chicago River	0	0	0	0	0	0	1	5	12	39	44
Clark Street	Chicago River	0	0	0	0	0	<1	<1	2	9	23	66
Loomis Street	South Branch Chicago River	0	0	<1	<1	1	9	27	28	21	5	9
36 th Street	Bubbly Creek	26	3	4	3	4	6	7	6	5	4	32
Interstate Highway 55	Bubbly Creek	14	4	4	5	7	8	12	7	8	8	23
Cicero Avenue	Chicago Sanitary and Ship Canal	<1	<1	1	2	8	16	15	19	18	9	13
B&O Central Railroad	Chicago Sanitary and Ship Canal	<1	<1	1	2	6	17	26	22	25	1	0
Lockport Powerhouse	Chicago Sanitary and Ship Canal	<1	1	3	10	11	24	13	12	16	7	3
-----Calumet River System-----												
C&W Indiana Railroad	Little Calumet River	0	0	<1	1	4	5	10	14	13	10	44
Halsted Street	Little Calumet River	0	0	0	<1	4	9	13	19	26	20	9
Ashland Avenue	Little Calumet River	0	<1	<1	1	6	15	12	9	10	11	36
Cicero Avenue	Calumet-Sag Channel	0	0	0	<1	3	10	24	20	21	16	7
Route 83	Calumet-Sag Channel	0	0	<1	2	11	10	16	12	19	15	14
-----Des Plaines River System-----												
Devon Avenue	Des Plaines River	0	0	0	0	2	8	19	12	5	7	47
Ogden Avenue	Des Plaines River	0	0	0	0	<1	10	17	11	6	7	49
Busse Lake Dam	Salt Creek	3	2	1	1	2	2	4	12	10	5	57
Wolf Road	Salt Creek	0	0	0	0	1	5	12	15	9	8	50

^aPercentages greater than one are rounded to the nearest whole number.

FIGURE 2: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT CHURCH STREET ON THE NORTH SHORE CHANNEL FROM JANUARY 1, 2019, THROUGH DECEMBER 31, 2019

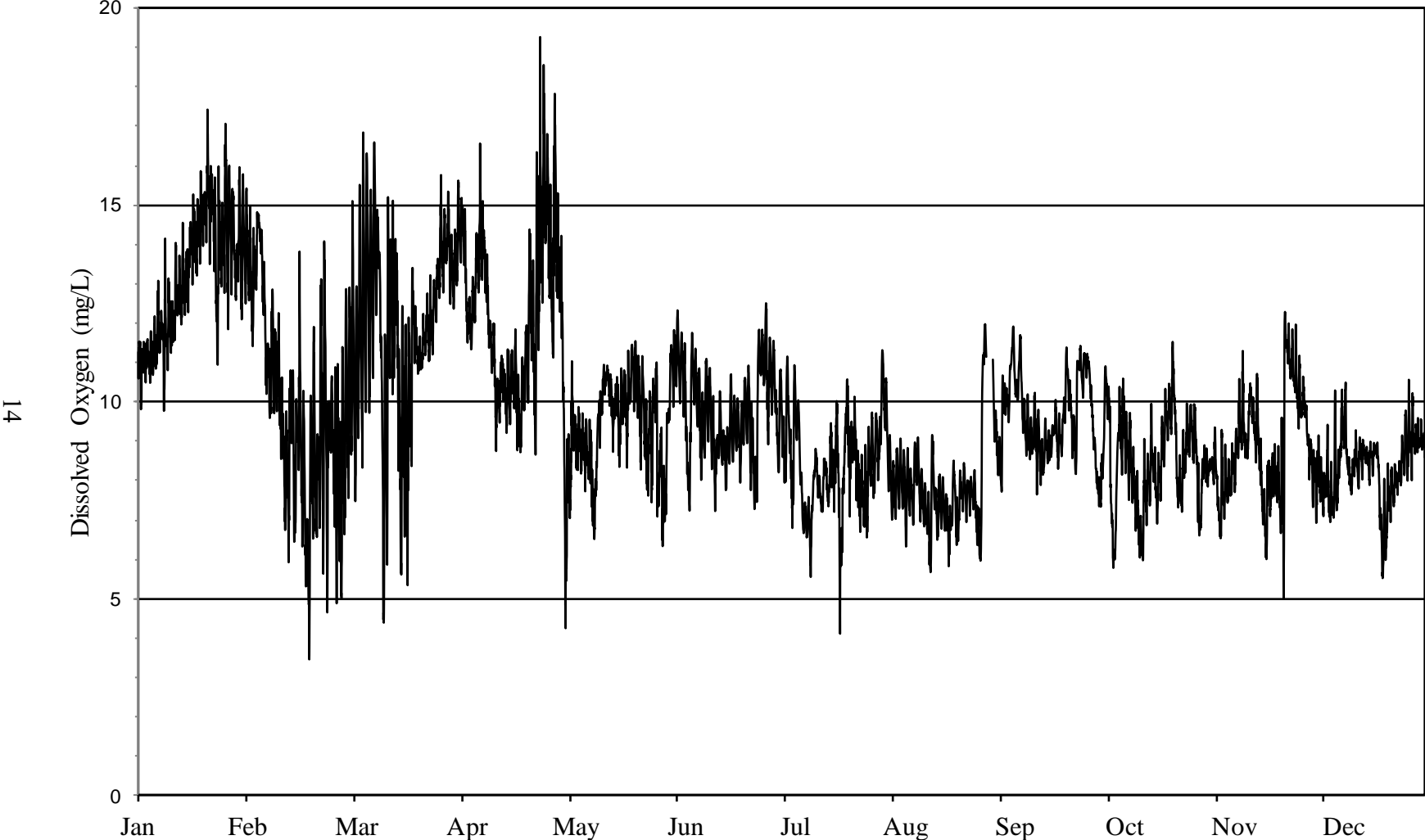


FIGURE 3: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT FOSTER AVENUE ON THE NORTH SHORE CHANNEL FROM JANUARY 1, 2019, THROUGH DECEMBER 31, 2019

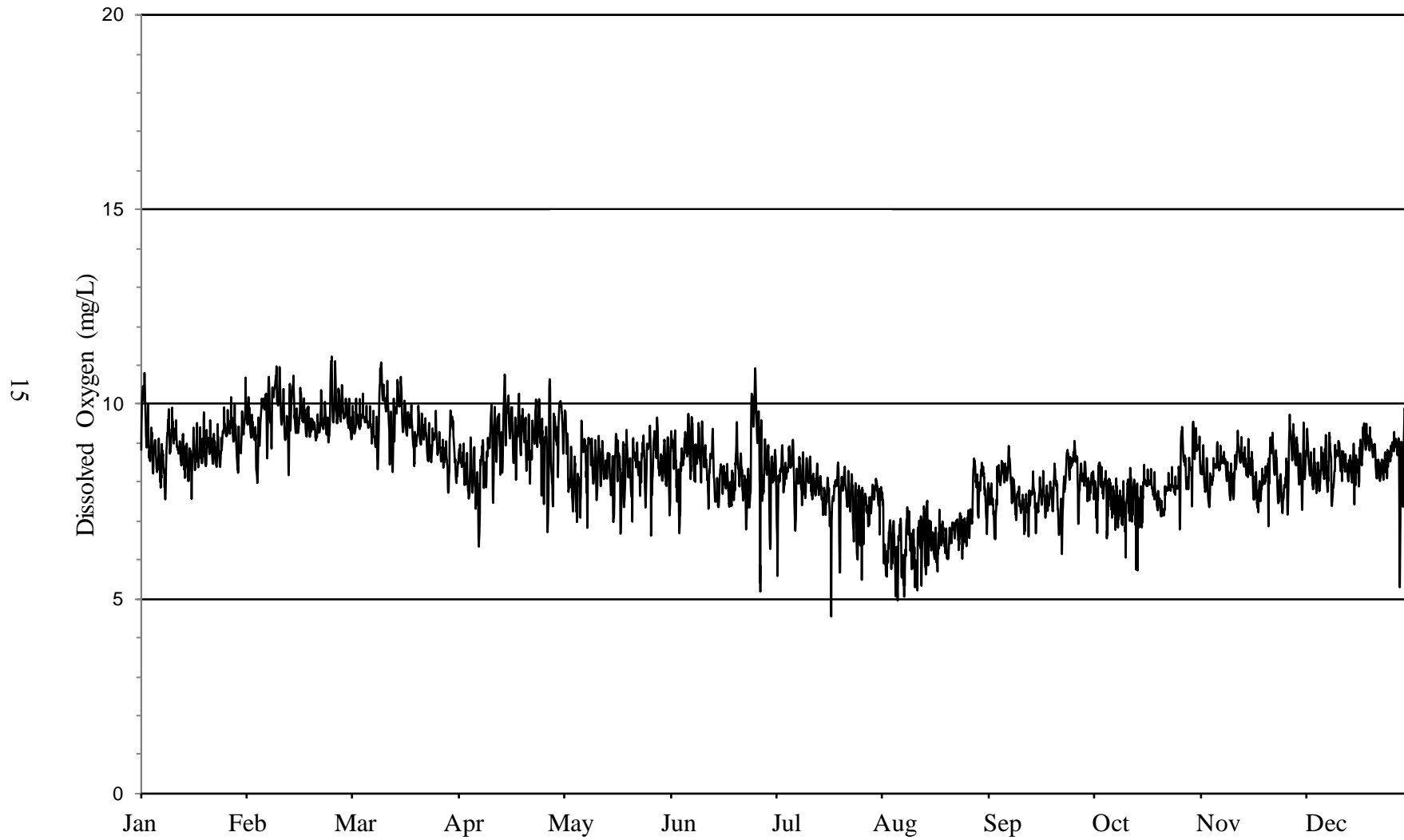


FIGURE 4: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT ADDISON STREET ON THE NORTH BRANCH CHICAGO RIVER FROM JANUARY 1, 2019, THROUGH DECEMBER 31, 2019

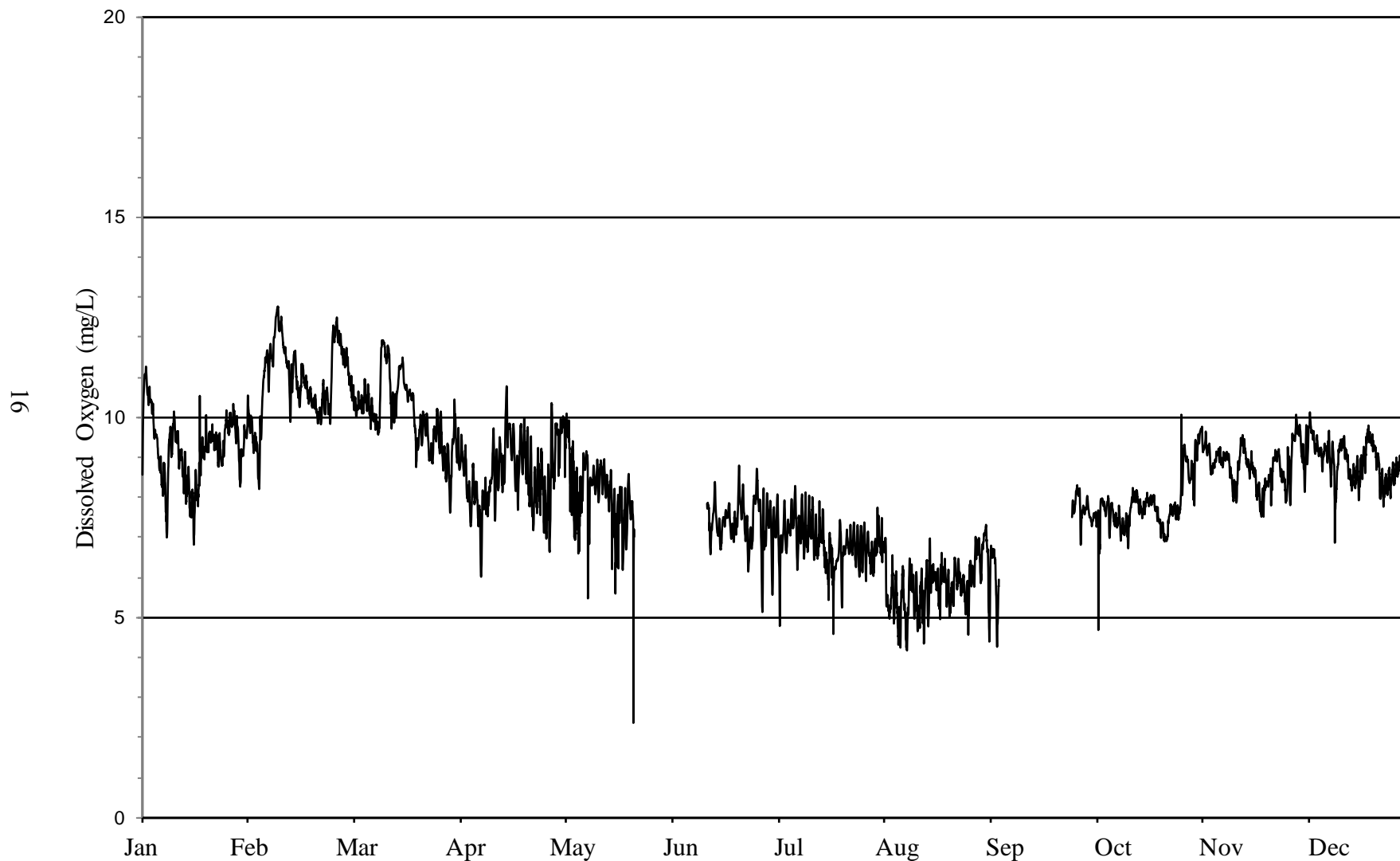


FIGURE 5: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT DIVISION STREET ON THE NORTH BRANCH CHICAGO RIVER FROM JANUARY 1, 2019, THROUGH DECEMBER 31, 2019

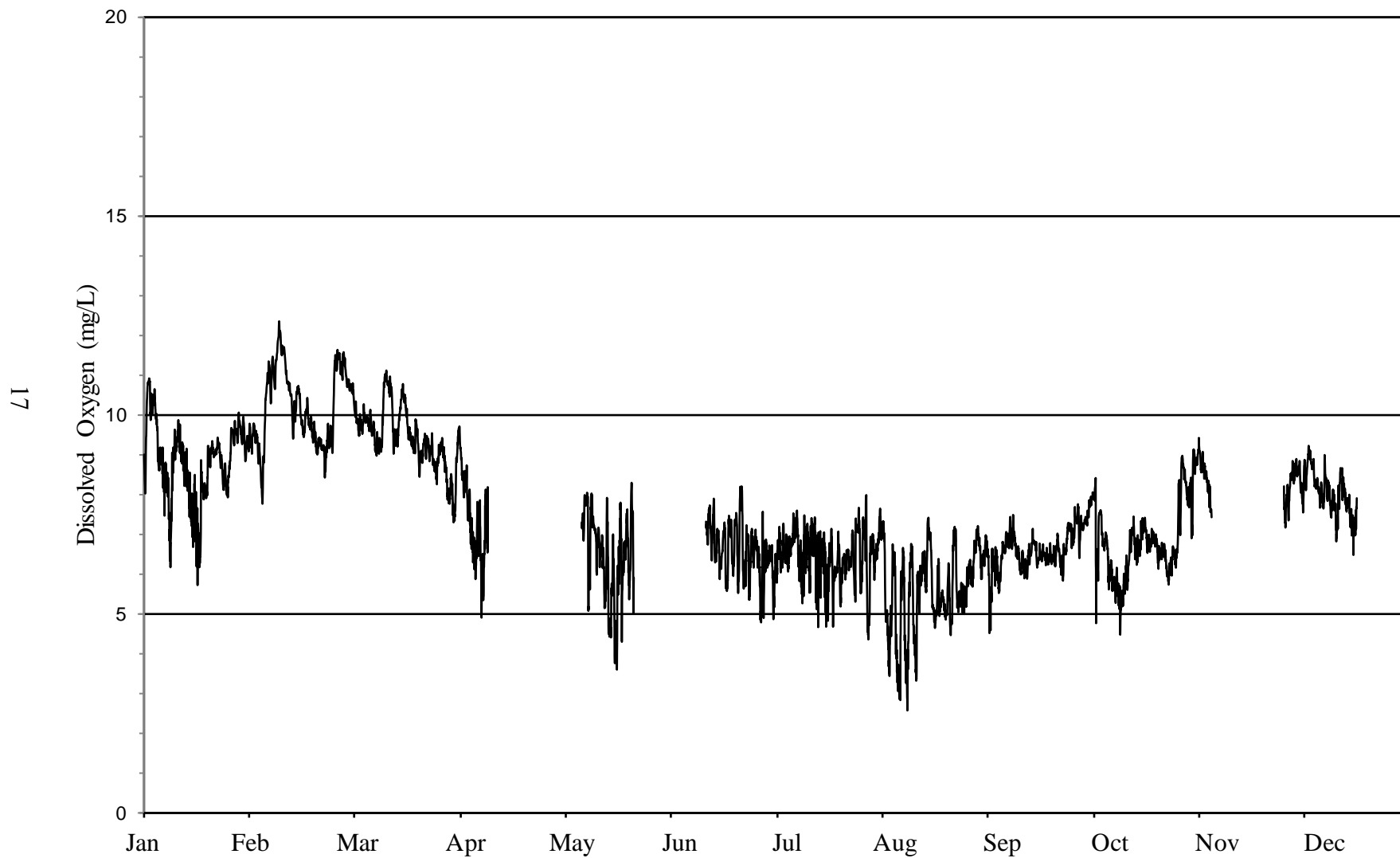
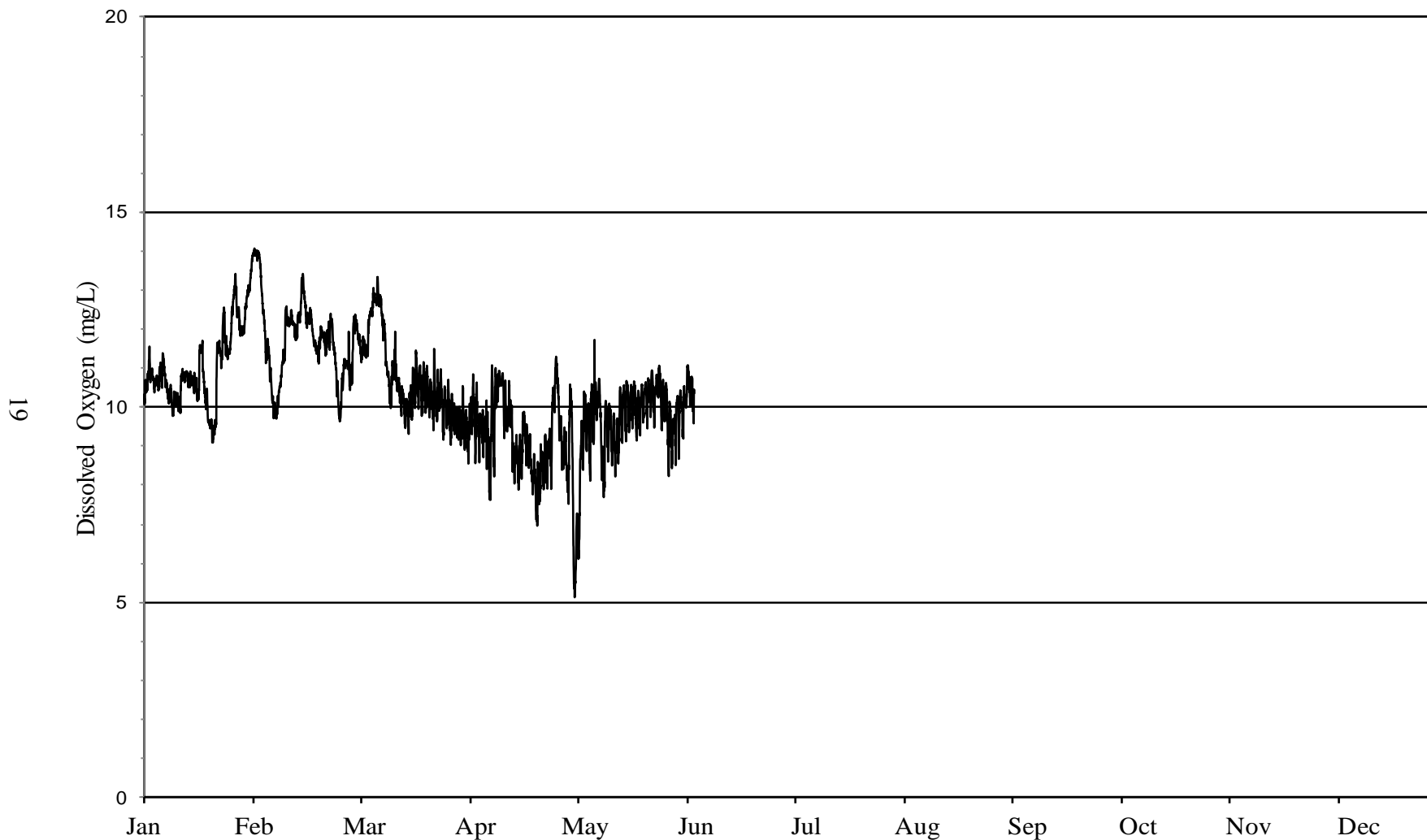


FIGURE 6: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT MICHIGAN AVENUE ON THE CHICAGO RIVER FROM MAY 22, 2019, THROUGH DECEMBER 31, 2019^a



^aThe Michigan Avenue station replaced Clark Street station which was discontinued in early June 2019 due to deteriorating infrastructure.

FIGURE 7: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT CLARK STREET ON THE CHICAGO RIVER FROM JANUARY 1, 2019, THROUGH JUNE 4, 2019^a



^aThe Clark Street station discontinued in early June 2019 due to deteriorating infrastructure and replaced by the Michigan Avenue station.

FIGURE 8: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT LOOMIS STREET ON THE SOUTH BRANCH OF THE CHICAGO RIVER FROM JANUARY 1, 2019, THROUGH DECEMBER 31, 2019



FIGURE 9: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT 36TH STREET ON BUBBLY CREEK FROM JANUARY 1, 2019, THROUGH DECEMBER 31, 2019

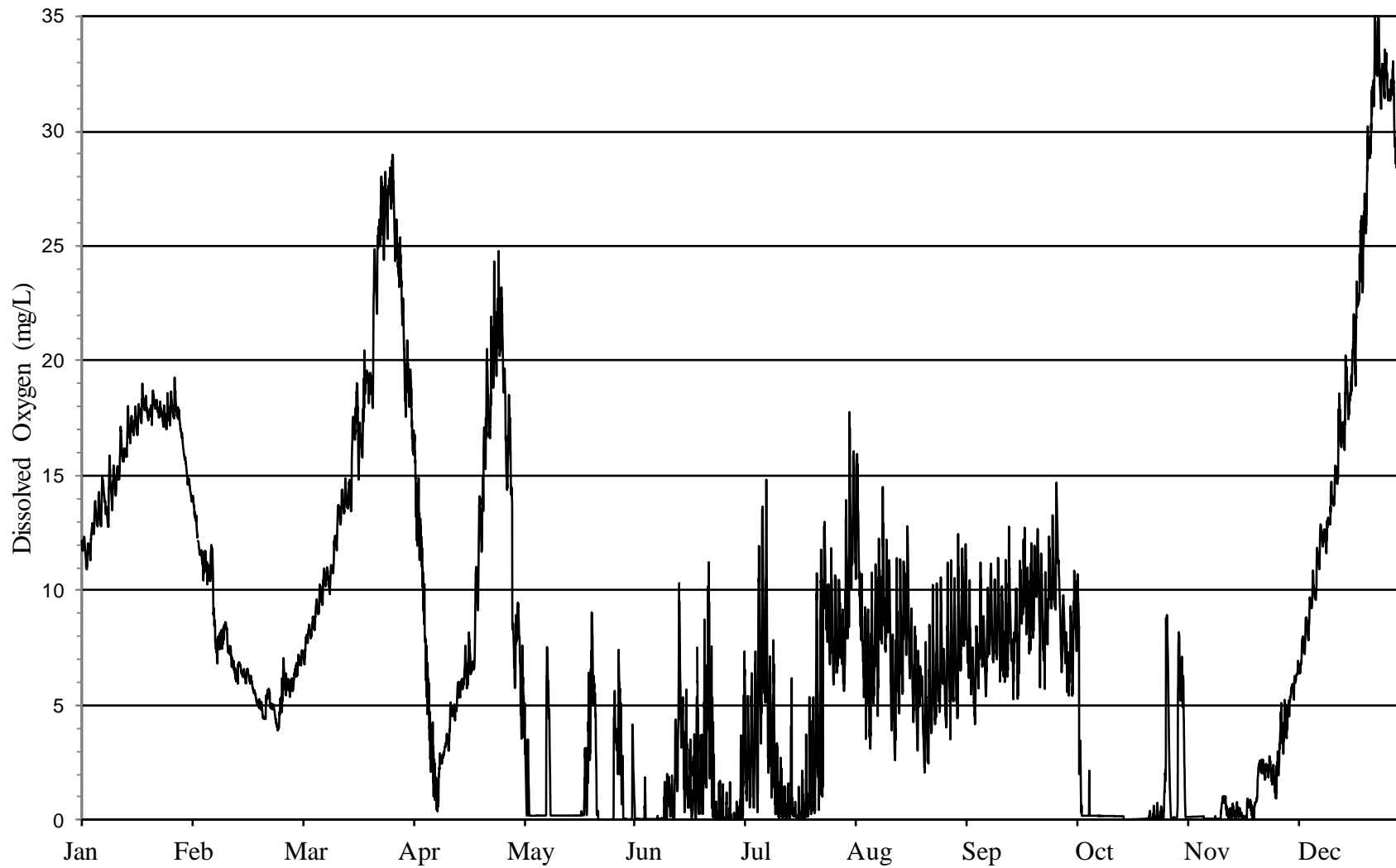


FIGURE 10: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT INTERSTATE HIGHWAY 55 ON BUBBLY CREEK FROM JANUARY 1, 2019, THROUGH DECEMBER 31, 2019

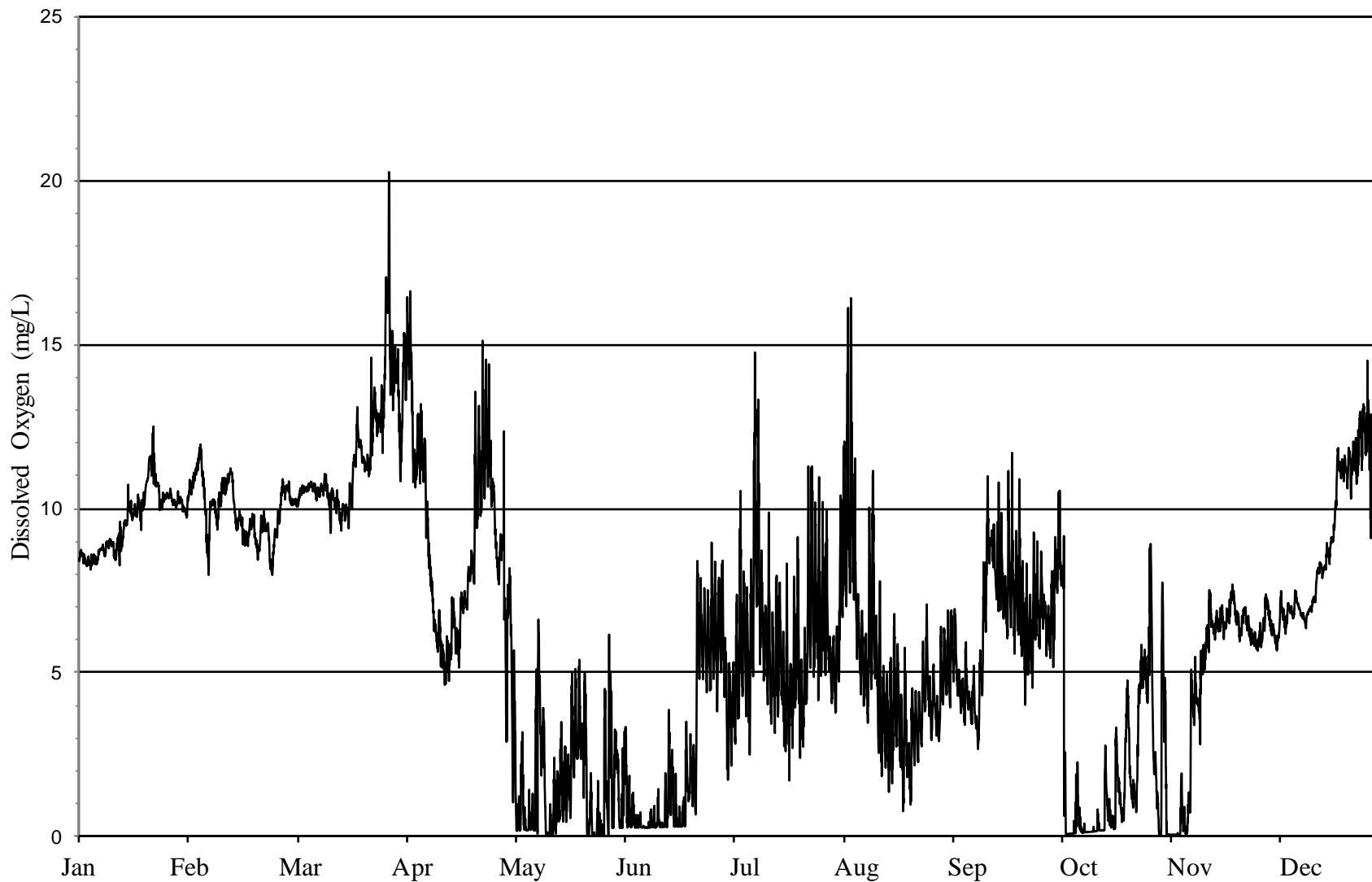


FIGURE 11: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT CICERO AVENUE ON THE CHICAGO SANITARY AND SHIP CANAL FROM JANUARY 1, 2019, THROUGH DECEMBER 31, 2019

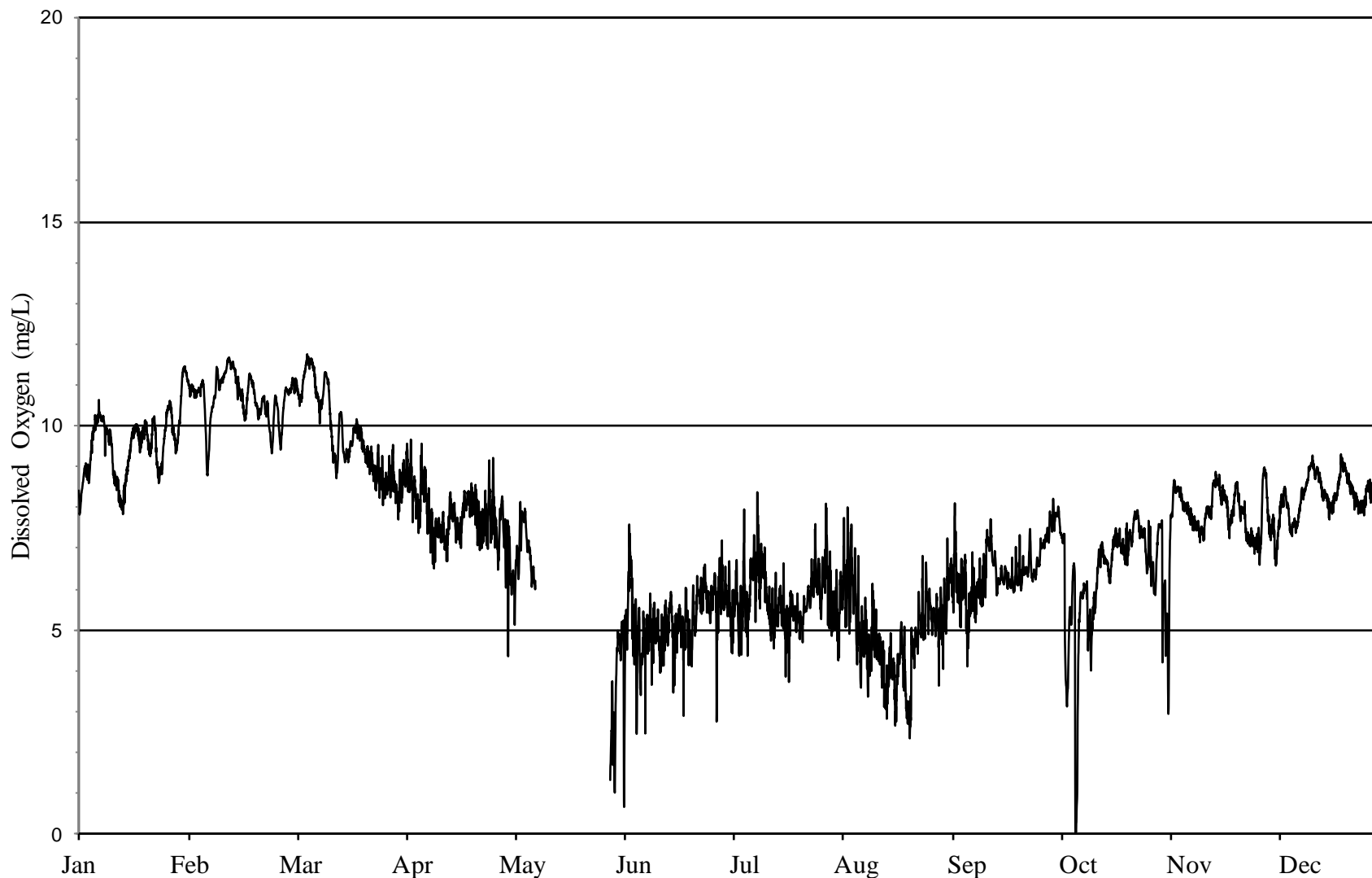


FIGURE 12: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT THE BALTIMORE AND OHIO RAILROAD ON THE SANITARY AND SHIP CANAL FROM JANUARY 1, 2019, THROUGH DECEMBER 31, 2019

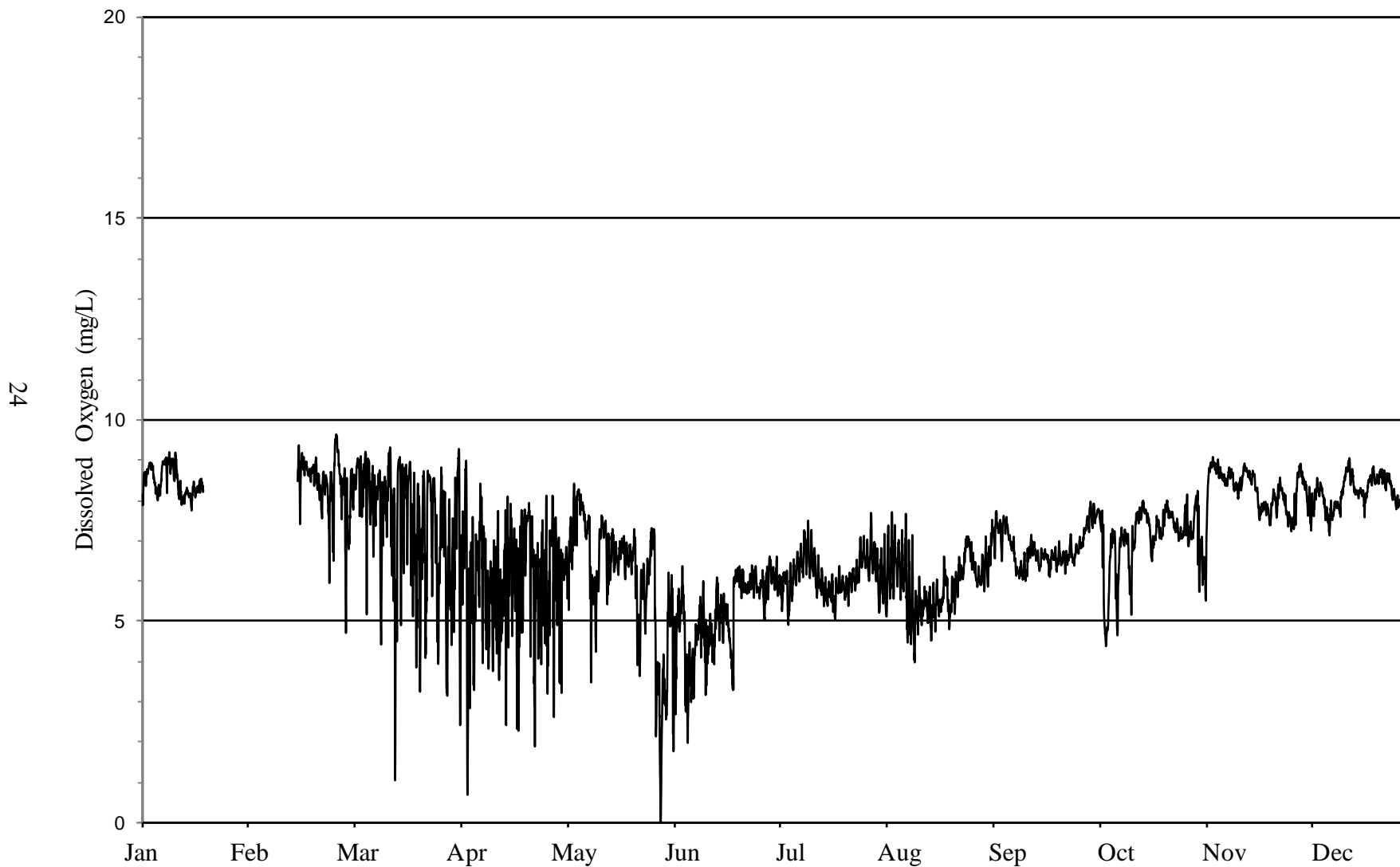


FIGURE 13: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT LOCKPORT POWERHOUSE ON THE CHICAGO SANITARY AND SHIP CANAL FROM JANUARY 1, 2019, THROUGH DECEMBER 31, 2019

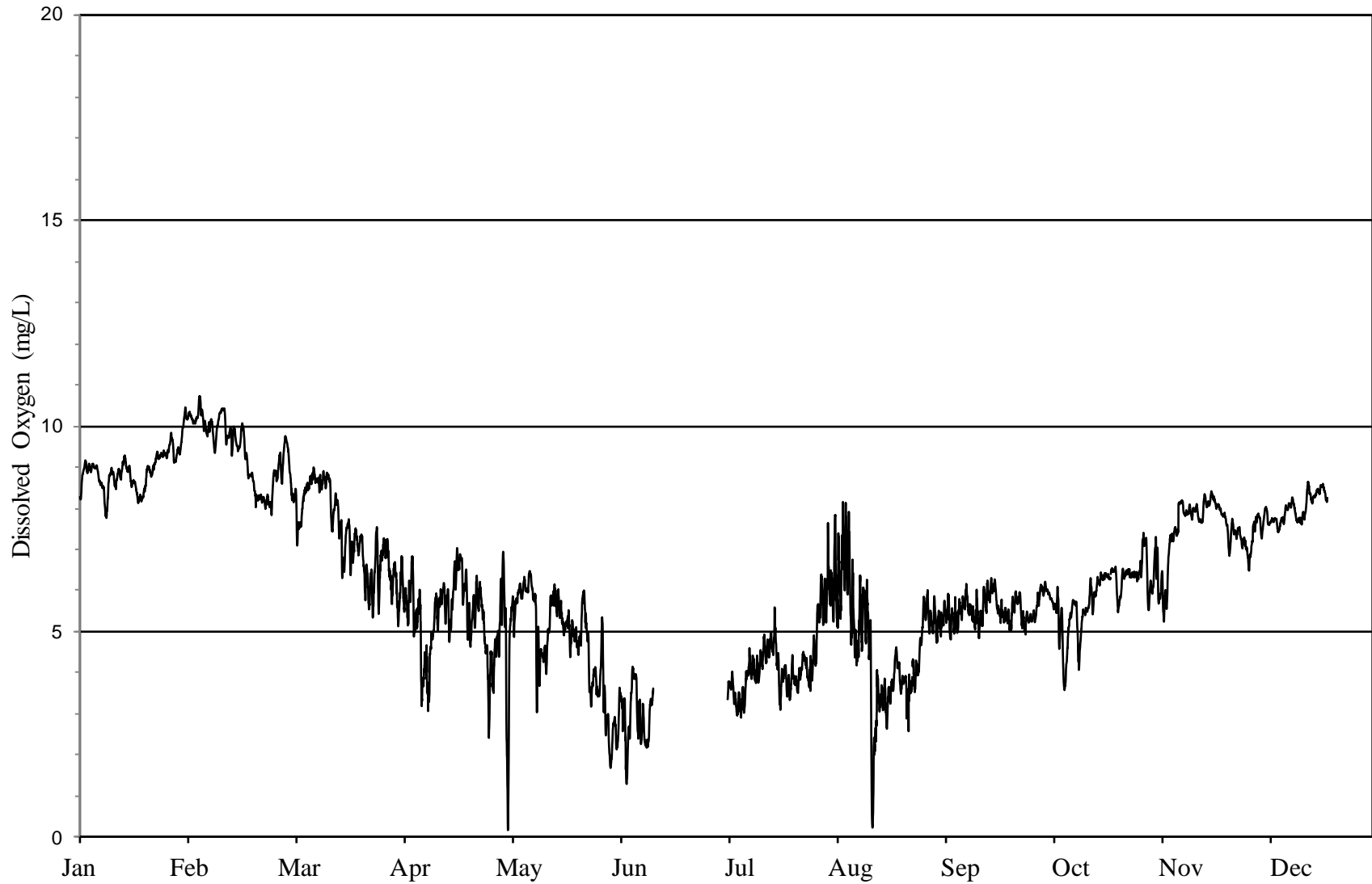


FIGURE 14: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT CHICAGO AND WESTERN INDIANA RAILROAD ON THE LITTLE CALUMET RIVER FROM JANUARY 1, 2019, THROUGH DECEMBER 31, 2019

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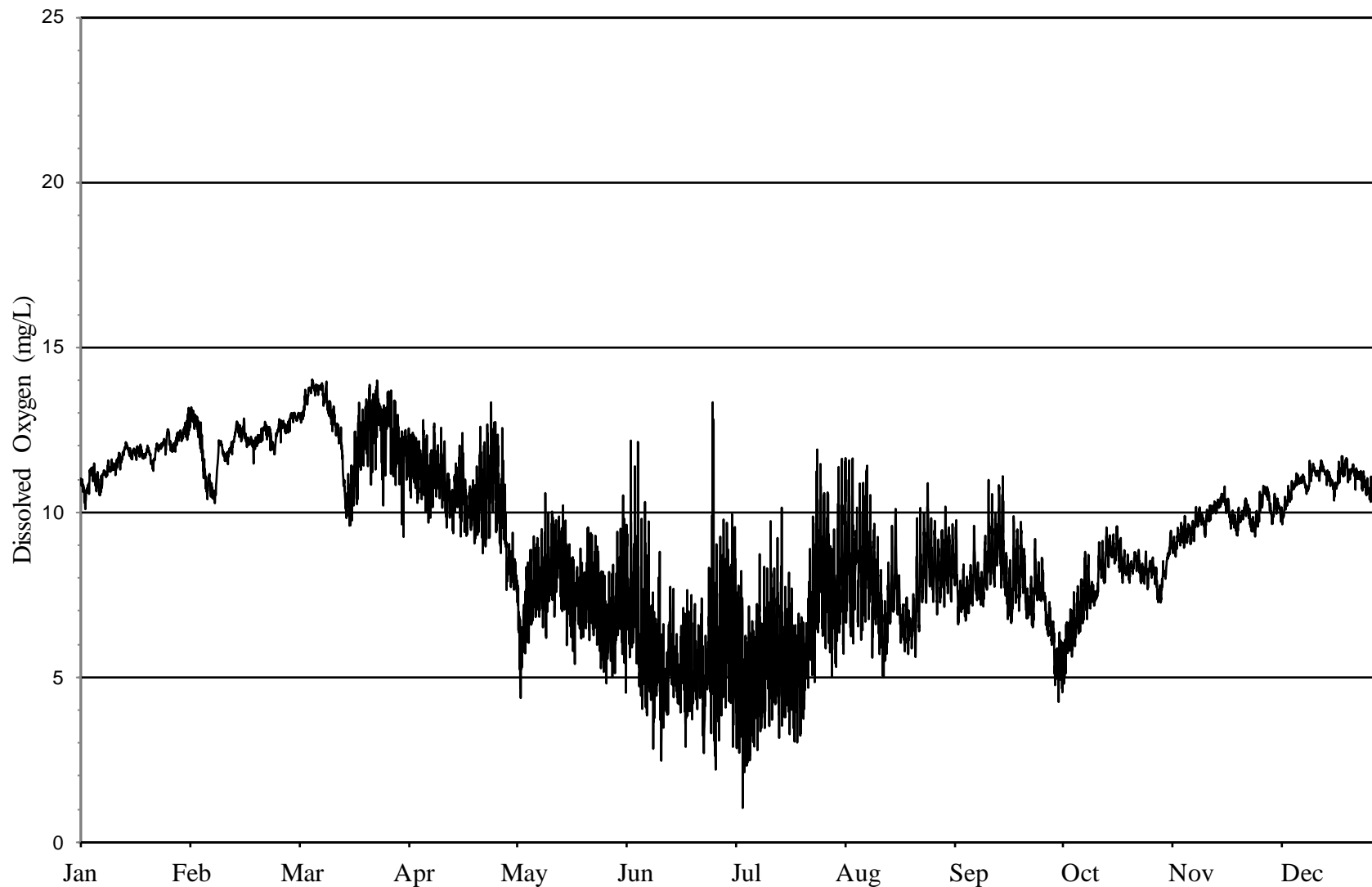


FIGURE 15: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT HALSTED STREET ON THE LITTLE CALUMET RIVER FROM JANUARY 1, 2019, THROUGH DECEMBER 31, 2019

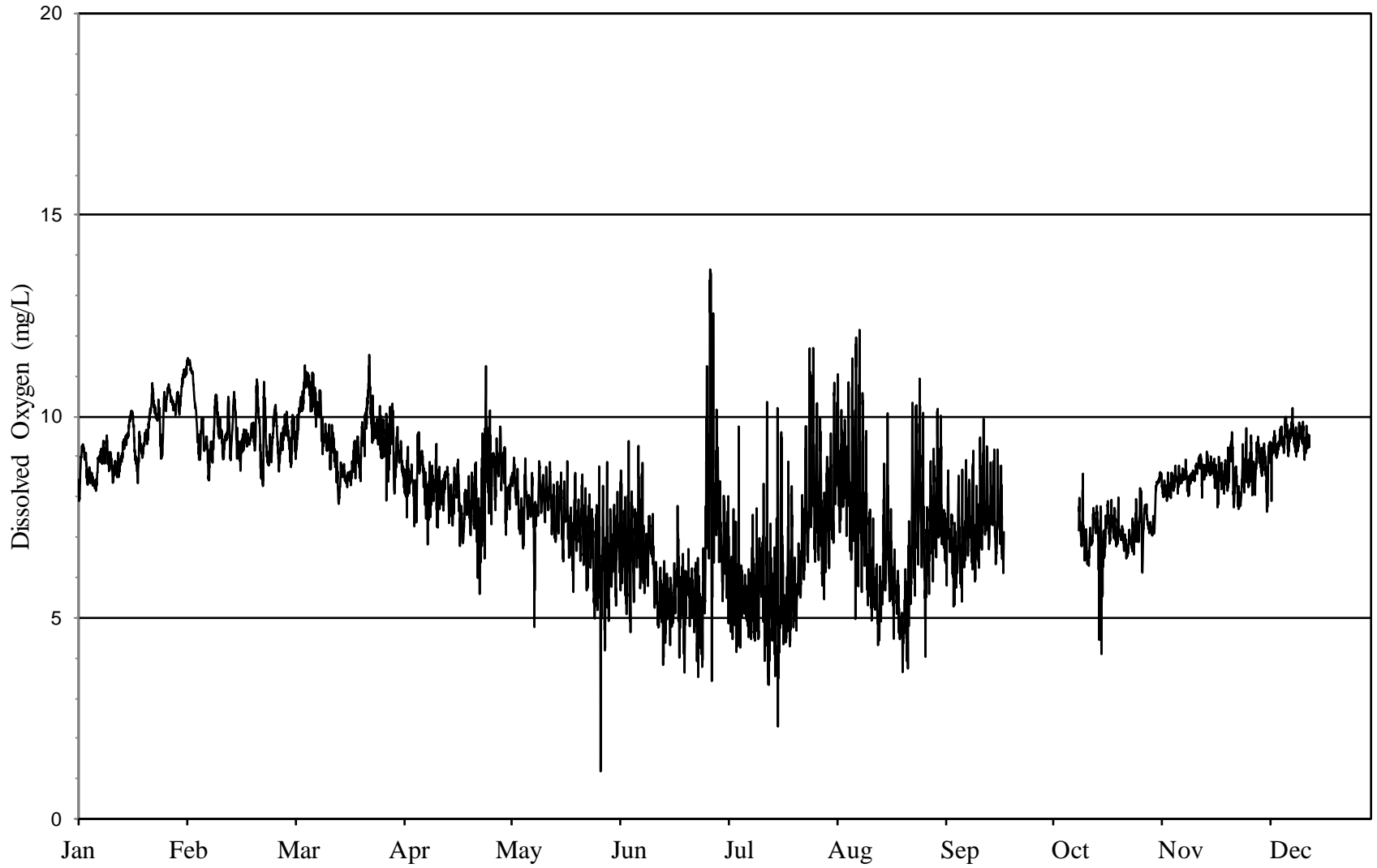


FIGURE 16: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT ASHLAND AVENUE ON THE LITTLE CALUMET RIVER FROM JANUARY 1, 2019, THROUGH DECEMBER 31, 2019

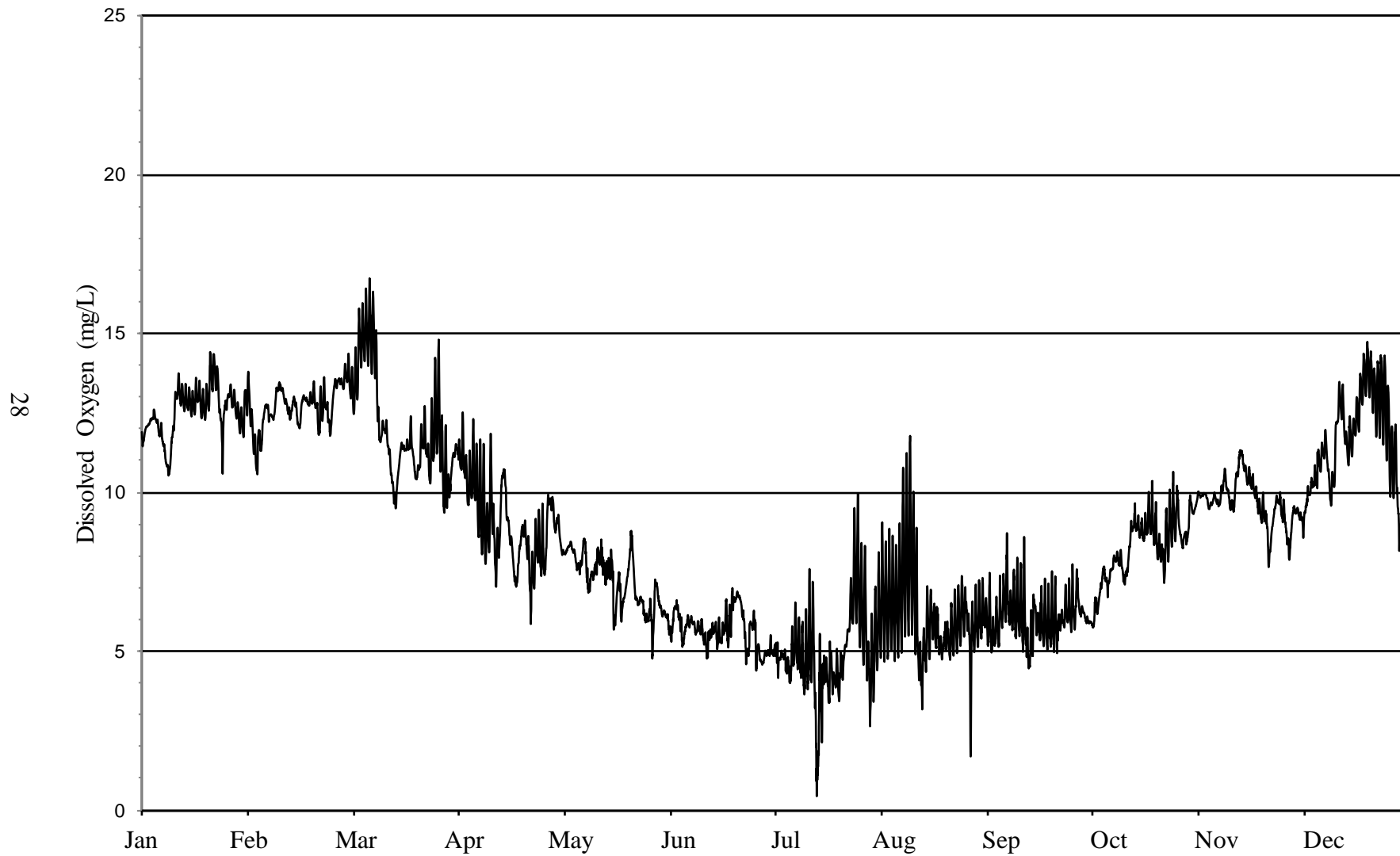


FIGURE 17: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT CICERO AVENUE ON THE CALUMET-SAG CHANNEL FROM JANUARY 1, 2019, THROUGH DECEMBER 31, 2019

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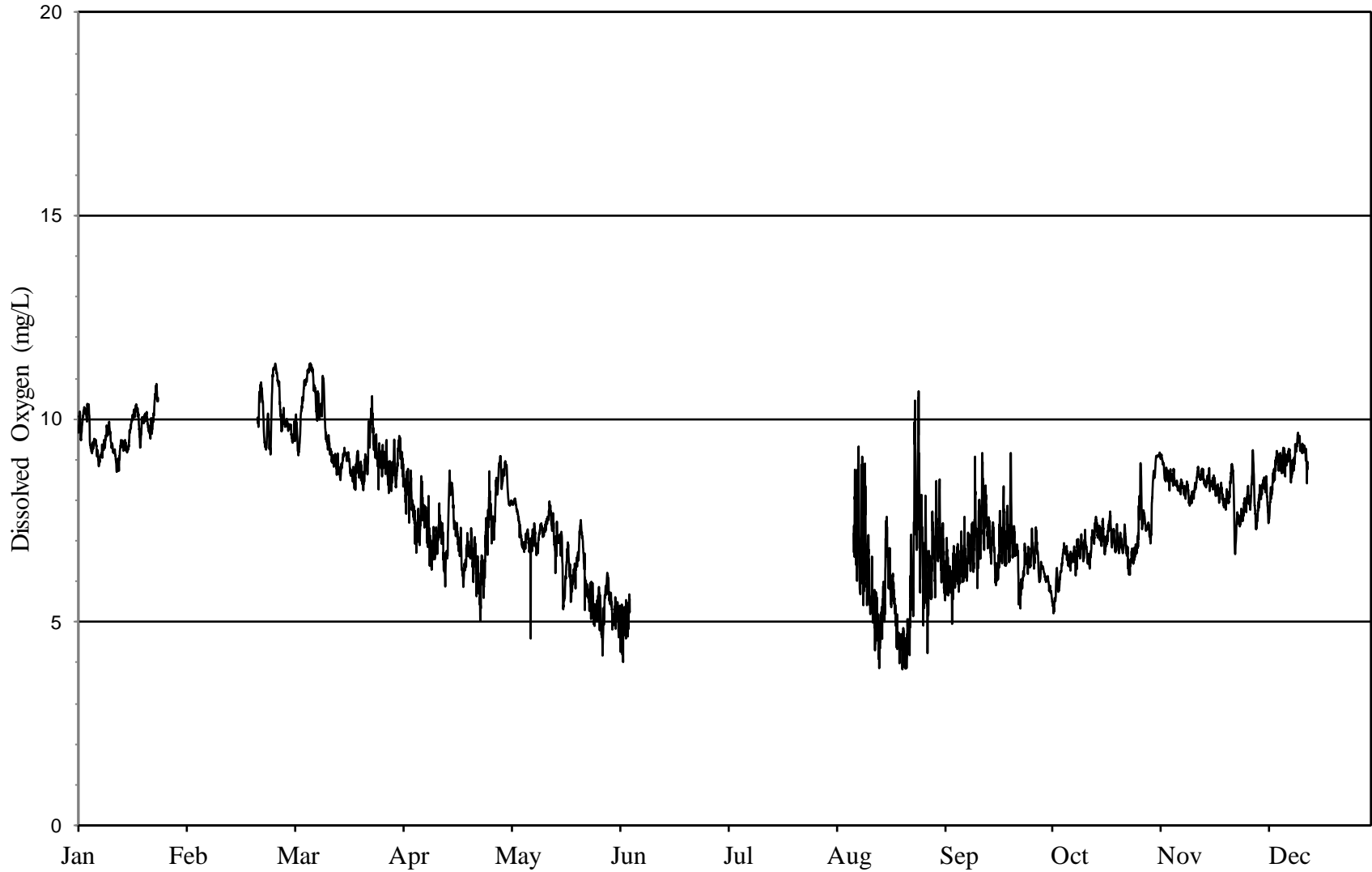


FIGURE 18: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT ROUTE 83 ON THE CALUMET-SAG CHANNEL FROM JANUARY 1, 2019, THROUGH DECEMBER 31, 2019

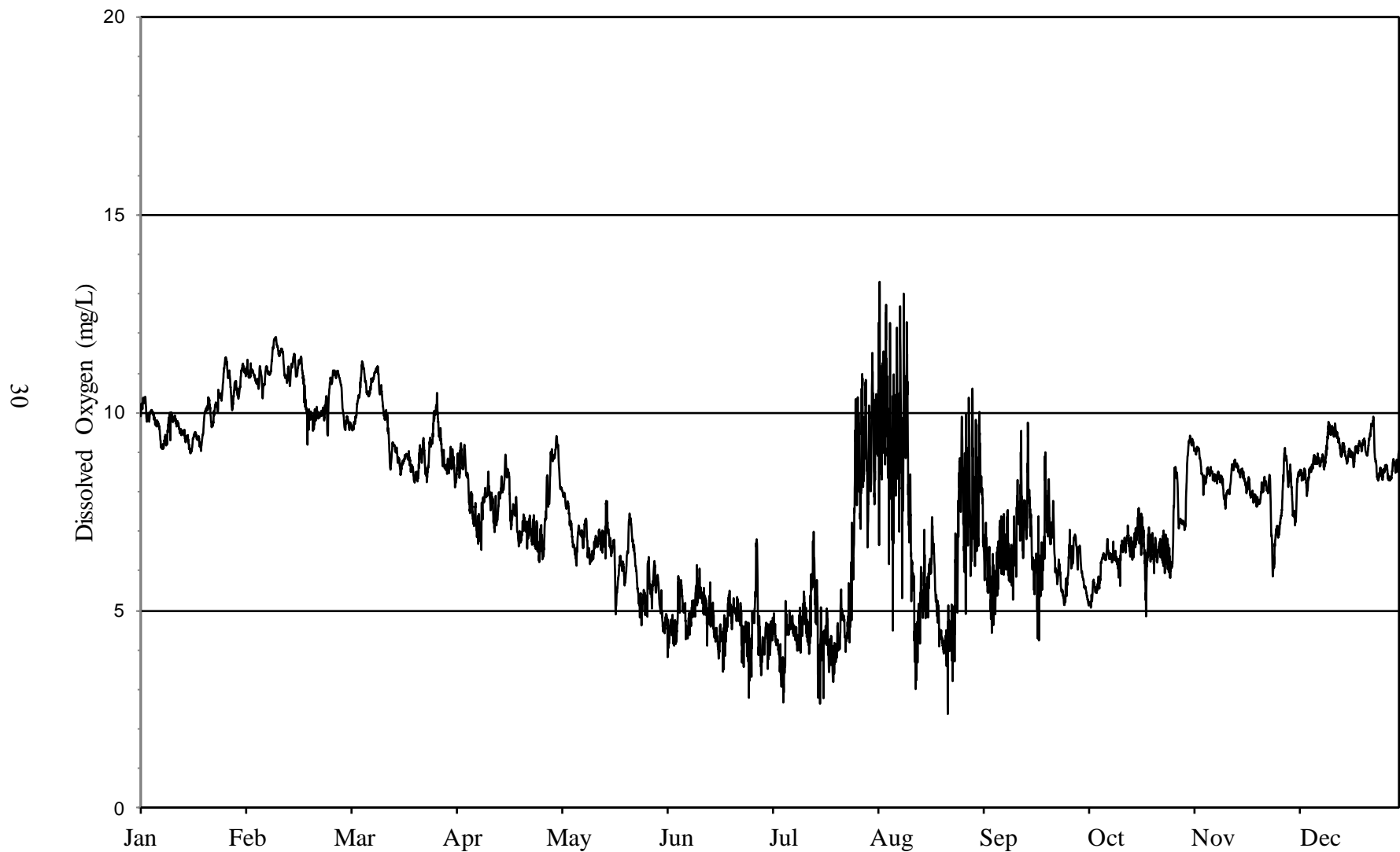


FIGURE 19: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT DEVON AVENUE ON THE DES PLAINES RIVER FROM JANUARY 1, 2019, THROUGH DECEMBER 31, 2019

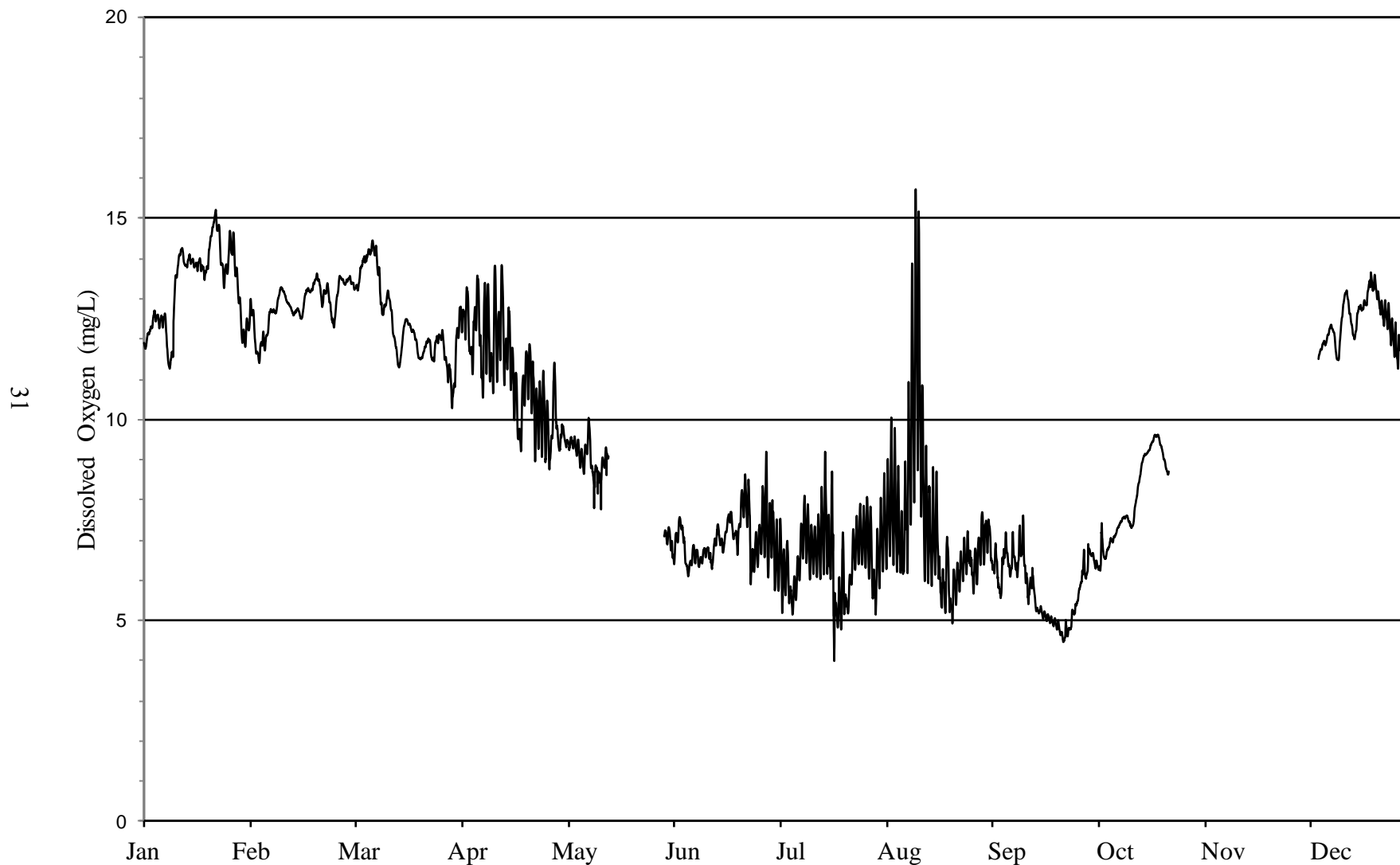


FIGURE 20: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT OGDEN AVENUE ON THE DES PLAINES RIVER FROM JANUARY 1, 2019, THROUGH DECEMBER 31, 2019

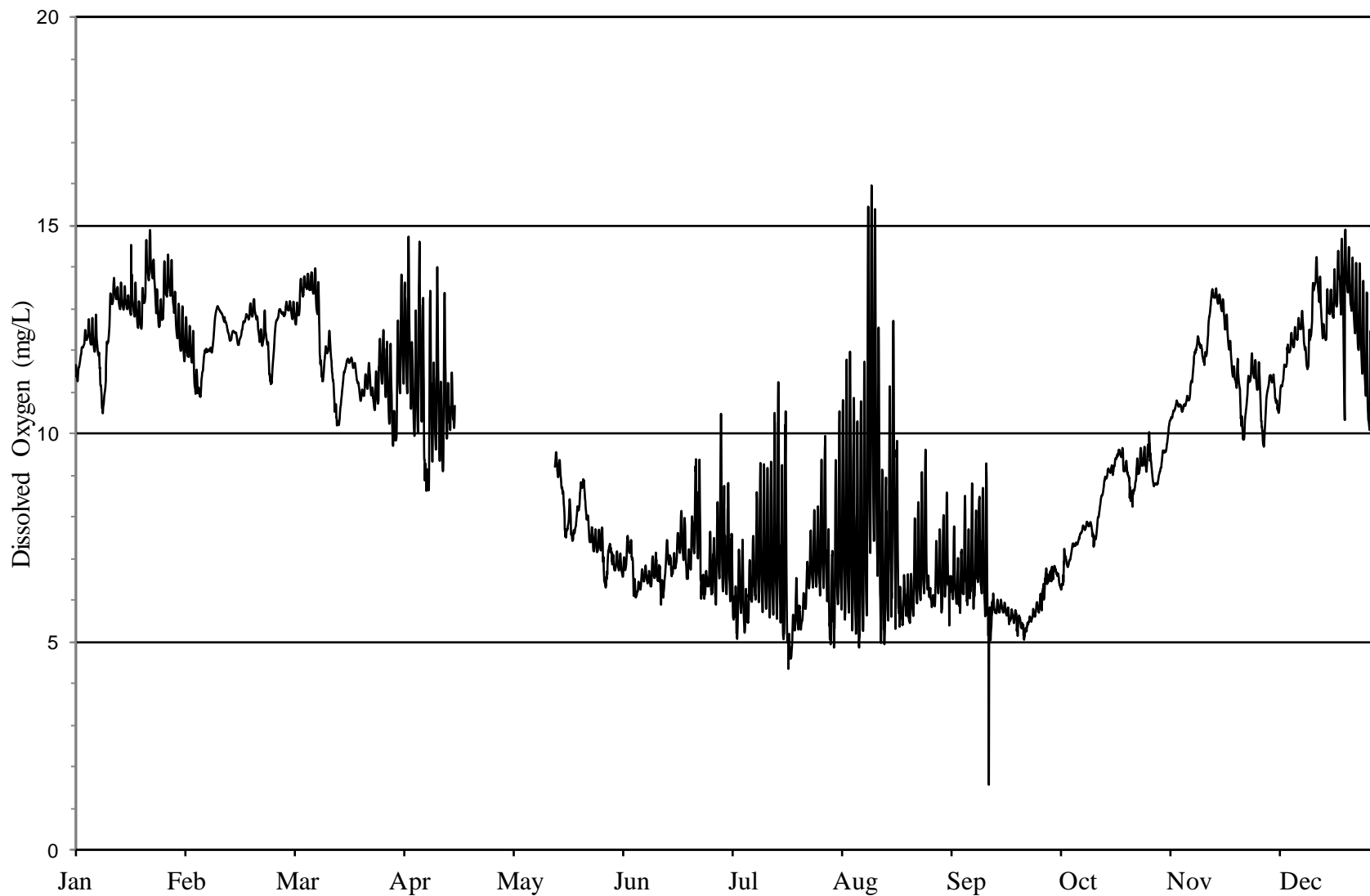


FIGURE 21: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT BUSSE LAKE DAM ON SALT CREEK FROM JANUARY 1, 2019, THROUGH DECEMBER 31, 2019

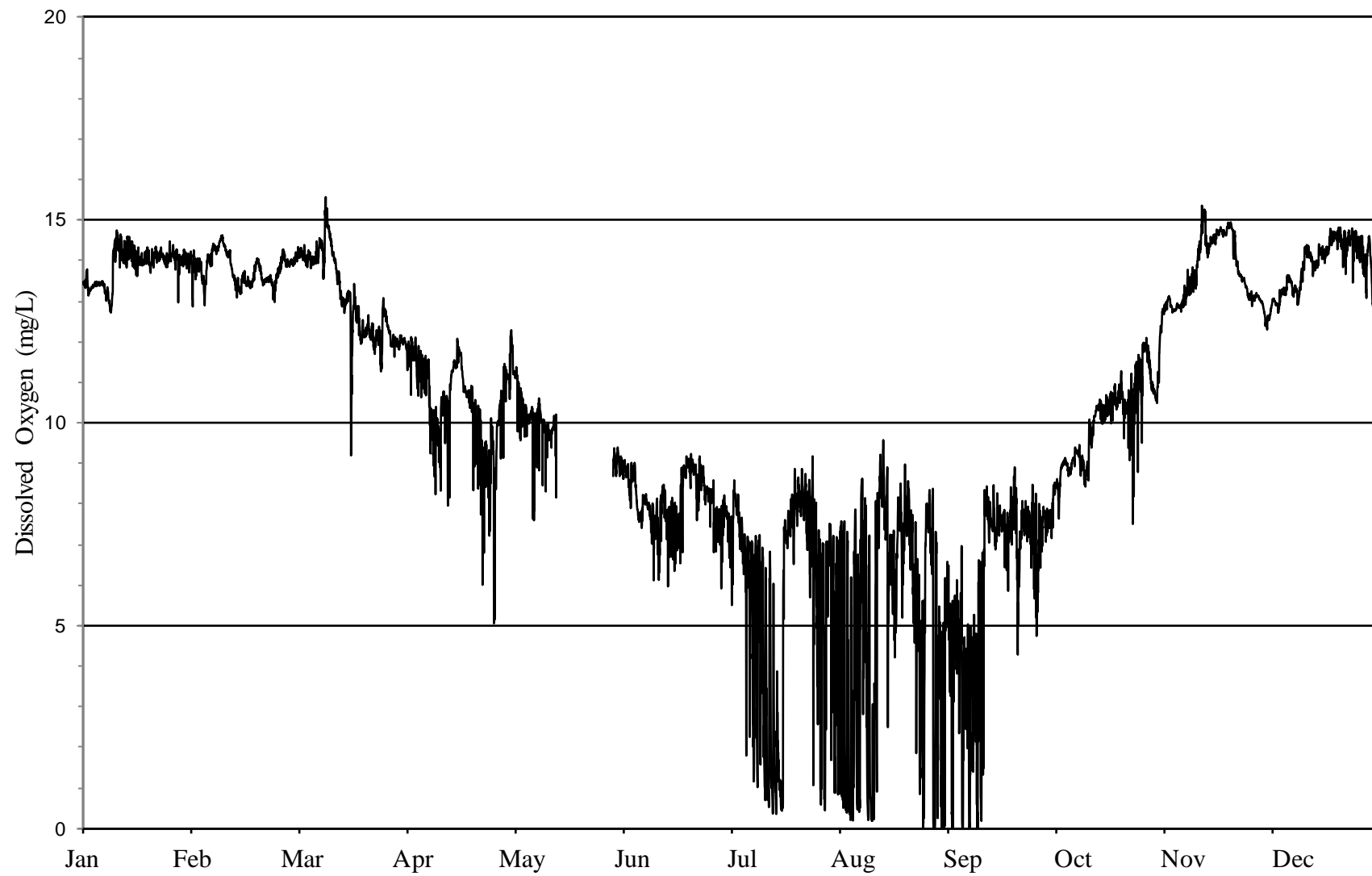


FIGURE 22: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT WOLF ROAD ON SALT CREEK FROM JANUARY 1, 2019, THROUGH DECEMBER 31, 2019

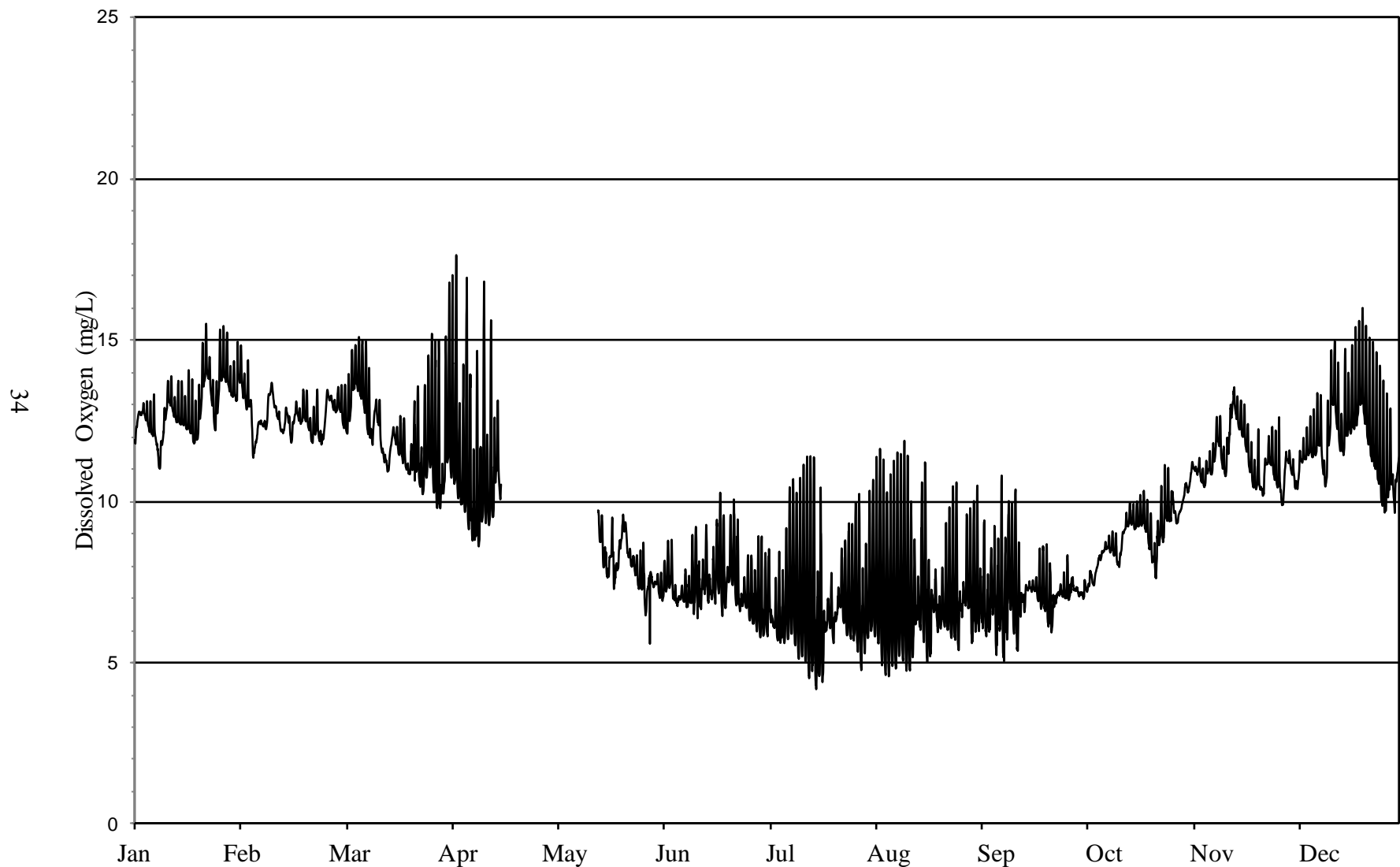


FIGURE 23: DISSOLVED OXYGEN CONCENTRATIONS MEASURED DURING CROSS-SECTIONAL SURVEYS AT THIRTY-SIXTH STREET IN BUBBLY CREEK IN MAY AND AUGUST 2019



FIGURE 24: DISSOLVED OXYGEN CONCENTRATIONS MEASURED DURING CROSS-SECTIONAL SURVEYS AT INTERSTATE HIGHWAY 55 IN BUBBLY CREEK IN MAY AND AUGUST 2019

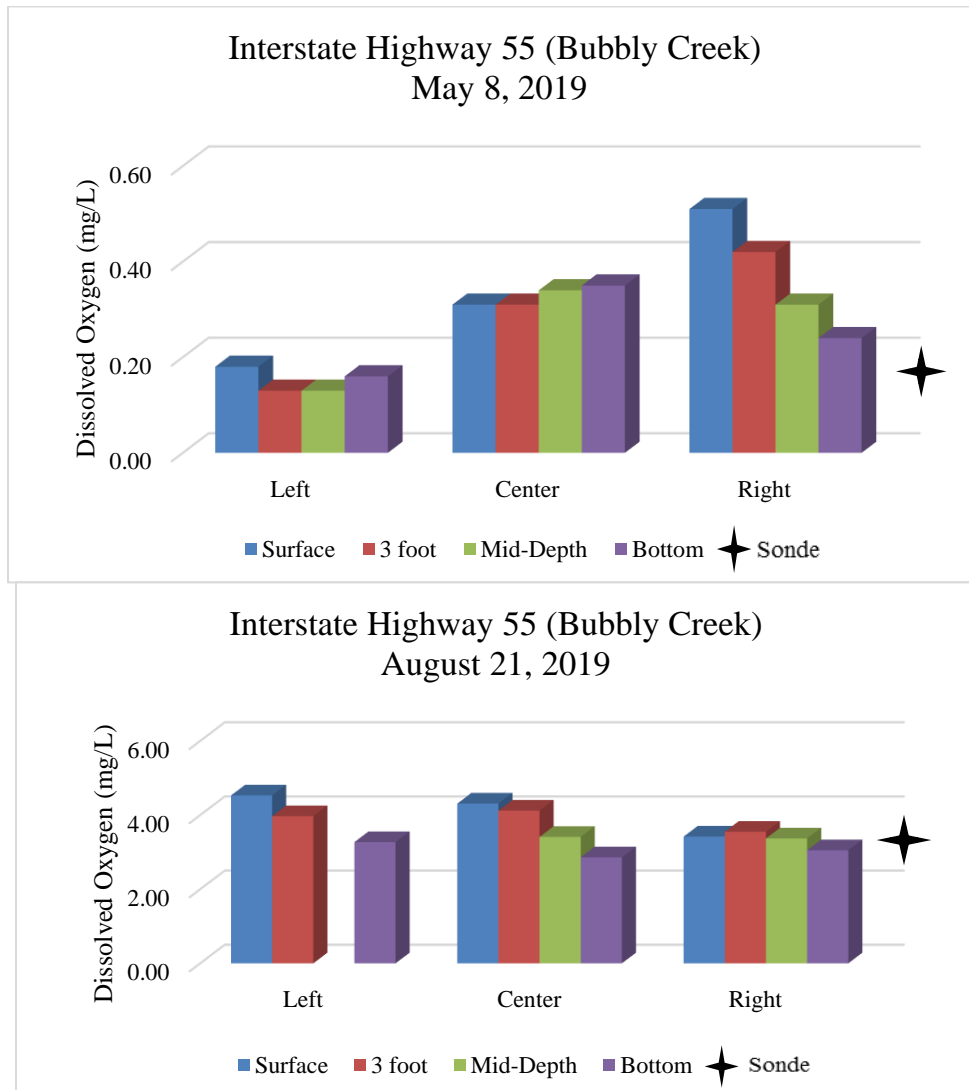


FIGURE 25: DISSOLVED OXYGEN CONCENTRATIONS MEASURED DURING CROSS-SECTIONAL SURVEYS AT CICERO IN THE CHICAGO SANITARY AND SHIP CANAL IN AUGUST 2019

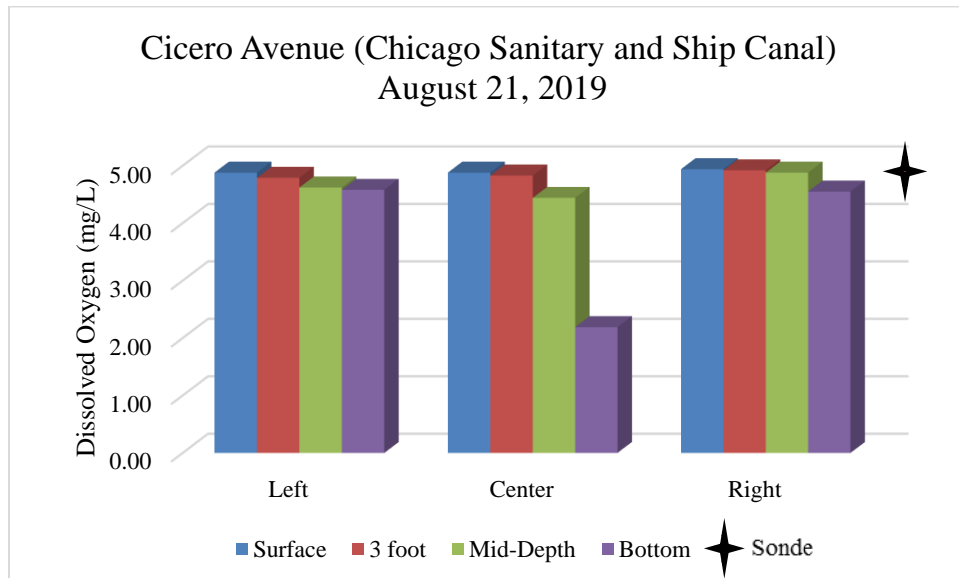
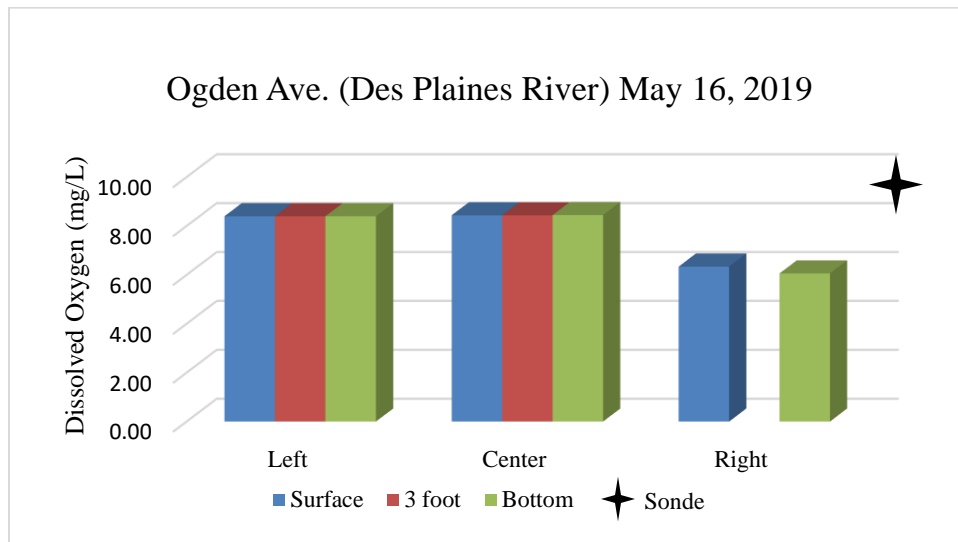


FIGURE 26: DISSOLVED OXYGEN CONCENTRATIONS MEASURED DURING CROSS-SECTIONAL SURVEYS AT OGDEN IN THE DES PLAINES RIVER IN MAY 2019



REFERENCES

Pescitelli, S. and T. Widloe, "Current Status of Fish Assemblages and the Sport Fishery in the Des Plaines River Watershed – Changes Over 44 years of Basin Surveys." Illinois Department of Natural Resources, Division of Fisheries Streams Program, Plano IL, 2018.

Metropolitan Water Reclamation District of Greater Chicago, "*Description of the Chicago Waterway System for the Use Attainability Analysis*," Research and Development Department, Report Number 08-15-R, March 2008.

APPENDIX AI

SUMMARY STATISTICS FOR DISSOLVED OXYGEN MEASURED DURING
CROSS-SECTIONAL SURVEYS IN 2019

TABLE A-1: SUMMARY STATISTICS FOR DISSOLVED OXYGEN MEASURED DURING CROSS-SECTIONAL SURVEYS IN 2019

Station and Date	Water Depth ¹ (ft.)			N ²	Minimum (mg/L)	Maximum (mg/L)	Mean (mg/L)	Standard Deviation (mg/L)	Coefficient of Variation (%)
	Left	Center	Right						
-----North Shore Channel-----									
Church Street									
04/25/2019	2.4	6.9	2.0	7	14.05	15.60	14.77	0.62	4.22
08/08/2019	2.5	7.9	1.8	7	7.57	7.77	7.67	0.08	1.03
10/01/2019	5.5	7.4	5.2	9	9.99	10.02	10.01	0.01	0.11
Foster Avenue									
04/25/2019	6.7	9.4	4.5	10	9.77	9.89	9.83	0.05	0.46
08/08/2019	3.3	9.7	2.5	7	5.97	6.26	6.12	0.12	1.90
10/01/2019	4.6	9.3	4.6	10	7.81	7.85	7.83	0.02	0.21
-----North Branch Chicago River-----									
Addison Street									
05/07/2019	9.0	9.3	5.1	10	8.12	8.72	8.24	0.18	2.24
08/15/2019	9.0	8.6	4.0	10	6.83	6.97	6.93	0.05	0.70
10/16/2019	8.0	8.4	4.0	11	7.83	7.86	7.84	0.01	0.15

I-IV

TABLE A-1 (Continued): SUMMARY STATISTICS FOR DISSOLVED OXYGEN MEASURED DURING CROSS-SECTIONAL SURVEYS IN 2019

Station and Date	Water Depth ¹ (ft.)			N ²	Minimum (mg/L)	Maximum (mg/L)	Mean (mg/L)	Standard Deviation (mg/L)	Coefficient of Variation (%)
	Left	Center	Right						
-----North Branch Chicago River (Continued)-----									
Division Street									
05/07/2019	10.5	18.8	14.0	12	6.97	7.62	7.37	0.15	2.01
08/15/2019	13.2	16.4	9.6	12	6.99	7.45	7.34	0.13	1.72
10/16/2019	12.1	16.0	8.6	12	7.21	7.44	7.40	0.06	0.84
-----Chicago River-----									
Clark Street									
05/07/2019	20.9	22.7	20.4	12	10.43	10.66	10.58	0.07	0.70
Michigan Avenue									
08/15/2019	17.5	23.6	21.8	12	8.32	8.48	8.38	0.05	0.60
10/16/2019	16.9	22.9	19.7	12	9.83	9.86	9.85	0.01	0.11

AI-2

TABLE A-1 (Continued): SUMMARY STATISTICS FOR DISSOLVED OXYGEN MEASURED DURING CROSS-SECTIONAL SURVEYS IN 2019

Station and Date	Water Depth ¹ (ft.)			N ²	Minimum (mg/L)	Maximum (mg/L)	Mean (mg/L)	Standard Deviation (mg/L)	Coefficient of Variation (%)
	Left	Center	Right						
-----South Branch Chicago River-----									
Loomis Street									
05/08/2019	21.7	20.3	14.2	12	7.36	7.56	7.49	0.06	0.85
08/21/2019	20.6	20.6	16.7	12	5.19	5.30	5.24	0.04	0.67
10/02/2019	17.9	22.8	15.8	12	8.02	8.06	8.04	0.01	0.13
-----Bubbly Creek-----									
36th Street									
05/08/2019	5.3	4.8	5.2	9	0.02	0.08	0.04	0.02	55.80
08/21/2019	3.6	4.7	5.5	8	2.56	10.50	6.94	2.66	38.37
10/02/2019	3.0	4.8	5.6	8	8.14	8.73	8.47	0.19	2.24
Interstate Highway 55									
05/08/2019	8.3	10.8	9.4	12	0.13	0.51	0.28	0.12	41.97
08/21/2019	5.6	10.3	9.4	11	2.86	4.53	3.62	0.53	14.74
10/02/2019	4.6	11.3	10.3	11	6.96	8.34	8.04	0.39	4.84

ε-IV

TABLE A-1 (Continued): SUMMARY STATISTICS FOR DISSOLVED OXYGEN MEASURED DURING CROSS-SECTIONAL SURVEYS IN 2019

Station and Date	Water Depth ¹ (ft.)			N ²	Minimum (mg/L)	Maximum (mg/L)	Mean (mg/L)	Standard Deviation (mg/L)	Coefficient of Variation (%)
	Left	Center	Right						
-----Chicago Sanitary and Ship Canal-----									
Cicero Avenue									
05/08/2019	15.3	17.3	9.5	12	6.09	6.52	6.42	0.12	1.92
08/21/2019	13.1	19.9	9.3	12	2.19	4.94	4.54	0.76	16.71
10/02/2019	13.3	18.2	7.1	11	7.21	7.37	7.30	0.05	0.68
B&O Railroad									
05/08/2019	12.8	20.1	9.8	12	7.27	7.63	7.50	0.13	1.74
08/21/2019	14.0	21.3	7.3	11	5.53	5.90	5.78	0.10	1.75
10/02/2019	13.0	21.0	7.2	11	7.60	7.66	7.63	0.02	0.26
-----Chicago Sanitary and Ship Canal (Continued)-----									
Lockport Powerhouse									
05/06/2019	26.3	27.3	13.5	12	5.95	6.11	6.01	0.05	0.81
08/05/2019	23.4	29.5	22.5	12	6.50	7.20	6.87	0.25	3.67
10/10/2019	26.7	30.9	32.0	12	5.42	5.58	5.48	0.05	0.95

A-4

TABLE A-1 (Continued): SUMMARY STATISTICS FOR DISSOLVED OXYGEN MEASURED
DURING CROSS-SECTIONAL SURVEYS IN 2019

Station and Date	Water Depth ¹ (ft.)			N ²	Minimum (mg/L)	Maximum (mg/L)	Mean (mg/L)	Standard Deviation (mg/L)	Coefficient of Variation (%)
	Left	Center	Right						
-----Little Calumet River-----									
C&W Indiana Railroad									
05/15/2019	10.3	15.9	10.5	12	9.22	9.57	9.41	0.10	1.07
08/07/2019	7.4	15.5	9.1	11	8.09	10.26	8.83	0.59	6.65
10/09/2019	9.1	15.8	9.1	12	7.80	8.85	8.38	0.37	4.41
Halsted Street									
05/15/2019	9.4	14.7	5.8	11	7.23	7.60	7.33	0.15	2.01
08/07/2019	5.6	14.9	5.4	10	7.09	9.55	8.70	0.77	8.84
10/09/2019	3.7	15.5	5.8	9	6.86	7.76	7.18	0.31	4.37
Ashland Avenue									
05/06/2019	1.8	6.8	1.1	7	7.78	7.88	7.83	0.04	0.51
08/05/2019	2.3	2.8	3.5	6	6.31	6.73	6.50	0.19	2.87
10/10/2019	1.9	3.7	2.6	6	7.63	7.71	7.68	0.03	0.42

C-IV

TABLE A-1 (Continued): SUMMARY STATISTICS FOR DISSOLVED OXYGEN MEASURED DURING CROSS-SECTIONAL SURVEYS IN 2019

Station and Date	Water Depth ¹ (ft.)			N ²	Minimum (mg/L)	Maximum (mg/L)	Mean (mg/L)	Standard Deviation (mg/L)	Coefficient of Variation (%)
	Left	Center	Right						
-----Calumet-Sag Channel-----									
Cicero Avenue									
05/15/2019	10.6	14.1	11.3	12	6.80	6.95	6.87	0.05	0.68
08/07/2019	9.4	13.5	4.3	11	7.36	8.44	7.66	0.31	4.08
10/09/2019	9.4	12.9	9.3	12	6.73	6.88	6.79	0.05	0.69
Route 83									
05/15/2019	16.7	14.5	7.8	11	7.23	7.49	7.35	0.10	1.30
08/07/2019	13.7	14.3	11.6	12	9.88	12.99	10.77	0.88	8.14
10/09/2019	13.9	14.2	11.0	12	6.52	6.57	6.54	0.01	0.23
-----Des Plaines River-----									
Devon Avenue									
05/16/2019	4.3	7.9	7.0	9	8.84	8.98	8.90	0.05	0.58
08/06/2019	2.1	2.4	1.2	6	6.34	6.43	6.37	0.04	0.67
10/15/2019	6.0	6.8	6.0	9	9.01	9.04	9.02	0.01	0.10

9-IV

TABLE A-1 (Continued): SUMMARY STATISTICS FOR DISSOLVED OXYGEN MEASURED DURING CROSS-SECTIONAL SURVEYS IN 2019

Station and Date	Water Depth ¹ (ft.)			N ²	Minimum (mg/L)	Maximum (mg/L)	Mean (mg/L)	Standard Deviation (mg/L)	Coefficient of Variation (%)
	Left	Center	Right						
Irving Park Road									
05/16/2019	5.9	8.3	6.3	10	8.39	8.44	8.41	0.01	0.17
08/06/2019	1.1	2.0	2.9	6	6.56	6.74	6.65	0.07	1.10
10/15/2019	6.0	7.1	6.1	9	8.95	8.98	8.97	0.01	0.15
Ogden Avenue									
05/16/2019	4.9	5.0	3.3	8	6.06	8.45	7.87	1.03	13.11
08/06/2019	1.5	1.2	1.6	6	4.92	5.70	5.42	0.39	7.14
10/15/2019	3.5	4.8	3.3	7	8.93	9.15	9.08	0.09	0.98
-----Salt Creek-----									
Busse Lake Dam									
05/16/2019	2.5	3.1	3.0	6	10.83	11.04	10.90	0.07	0.68
08/06/2019	1.8	2.6	2.8	6	8.67	8.93	8.78	0.11	1.25
10/15/2019	3.4	3.3	3.4	6	10.07	10.23	10.14	0.06	0.59
Wolf Road									
05/16/2019	0.0	2.4	2.3	6	8.31	8.39	8.36	0.04	0.45
08/06/2019	0.0	2.1	1.6	6	6.35	6.52	6.42	0.07	1.04
10/15/2019	0.0	2.8	2.0	6	9.73	9.75	9.74	0.01	0.06

¹Water depth at the time of cross-sectional survey. Exact measurement location may differ slightly during each event.

²Number of dissolved oxygen measurements across transects.