

Protecting Our Water Environment



Metropolitan Water Reclamation District of Greater Chicago

***MONITORING AND RESEARCH
DEPARTMENT***

REPORT NO. 17-38

CONTINUOUS DISSOLVED OXYGEN MONITORING

IN THE CHICAGO AREA WATERWAYS

DURING 2016

August 2017

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TABLE OF CONTENTS

	<u>Page</u>
LIST OF TABLES	ii
LIST OF FIGURES	iii
LIST OF ABBREVIATIONS	vi
ACKNOWLEDGMENTS	vii
DISCLAIMER	vii
INTRODUCTION	1
MONITORING LOCATIONS AND APPLICABLE DISSOLVED OXYGEN STANDARDS	2
Locations and Descriptions	2
Designated Uses for 2016	2
Dissolved Oxygen Water Quality Standards for 2016	2
MATERIALS AND METHODS	9
Water Quality Monitors	9
Data Management and Review	9
Cross-Sectional Surveys	10
RESULTS	11
REFERENCES	38
APPENDIX	
Summary Statistics for Dissolved Oxygen Measured During Cross-Sectional Surveys in 2016	

LIST OF TABLES

<u>Table No.</u>		<u>Page</u>
1	Continuous Dissolved Oxygen Monitoring Stations During 2016	4
2	Minimum, Maximum, and Mean Hourly Dissolved Oxygen Concentrations During 2016	12
3	Number and Percent of Dissolved Oxygen Values Not Meeting Acceptance Criteria During 2016	13
4	Percent of Dissolved Oxygen Values in Selected Ranges During 2016	15
AI-1	Summary Statistics for Dissolved Oxygen Measured During Cross-Sectional Surveys in 2016	AI-1

LIST OF FIGURES

<u>Figure No.</u>		<u>Page</u>
1	2016 Continuous Dissolved Oxygen Monitoring Stations	3
2	Dissolved Oxygen Concentration Measured Hourly at Church Street on the North Shore Channel from May 13, 2016, Through December 31, 2016	16
3	Dissolved Oxygen Concentration Measured Hourly at Foster Avenue on the North Shore Channel from January 1, 2016, Through December 31, 2016	17
4	Dissolved Oxygen Concentration Measured Hourly at Central Park Avenue on the North Branch Chicago River from August 18, 2016, Through December 31, 2016	18
5	Dissolved Oxygen Concentration Measured Hourly at Addison Street on the North Branch Chicago River from January 1, 2016, Through December 31, 2016	19
6	Dissolved Oxygen Concentration Measured Hourly at Division Street on the North Branch Chicago River from January 1, 2016, Through December 31, 2016	20
7	Dissolved Oxygen Concentration Measured Hourly at Clark Street on the Chicago River from January 1, 2016, Through December 31, 2016	21
8	Dissolved Oxygen Concentration Measured Hourly at Loomis Street on the South Branch Chicago River from January 1, 2016, Through December 31, 2016	22
9	Dissolved Oxygen Concentration Measured Hourly at 36th Street on Bubbly Creek from January 1, 2016, Through December 31, 2016	23
10	Dissolved Oxygen Concentration Measured Hourly at Interstate Highway 55 on Bubbly Creek from January 1, 2016, Through December 31, 2016	24
11	Dissolved Oxygen Concentration Measured Hourly at Cicero Avenue on the Chicago Sanitary and Ship Canal from January 1, 2016, Through December 31, 2016	25

LIST OF FIGURES (Continued)

<u>Figure No.</u>		<u>Page</u>
12	Dissolved Oxygen Concentration Measured Hourly at B&O Central Railroad on the Chicago Sanitary and Ship Canal from January 1, 2016, Through December 31, 2016	26
13	Dissolved Oxygen Concentration Measured Hourly at Lockport Powerhouse on the Chicago Sanitary and Ship Canal from January 1, 2016, Through December 31, 2016	27
14	Dissolved Oxygen Concentration Measured Hourly at C&W Indiana Railroad on the Little Calumet River from January 1, 2016, Through December 31, 2016	28
15	Dissolved Oxygen Concentration Measured Hourly at Halsted Street on the Little Calumet River from January 1, 2016, Through December 31, 2016	29
16	Dissolved Oxygen Concentration Measured Hourly at Ashland Avenue on the Little Calumet River from January 1, 2016, Through December 31, 2016	30
17	Dissolved Oxygen Concentration Measured Hourly at Cicero Avenue on the Calumet-Sag Channel from January 1, 2016, Through December 31, 2016	31
18	Dissolved Oxygen Concentration Measured Hourly at Route 83 on the Calumet-Sag Channel from January 1, 2016, Through December 31, 2016	32
19	Dissolved Oxygen Concentration Measured Hourly at Devon Avenue on the Des Plaines River from January 1, 2016, Through December 31, 2016	33
20	Dissolved Oxygen Concentration Measured Hourly at Ogden Avenue on the Des Plaines River from March 18, 2016, Through December 31, 2016	34
21	Dissolved Oxygen Concentration Measured Hourly at Busse Lake Dam on Salt Creek from January 1, 2016, Through December 31, 2016	35

LIST OF FIGURES (Continued)

<u>Figure No.</u>		<u>Page</u>
22	Dissolved Oxygen Concentration Measured Hourly at J. F. Kennedy Boulevard on Salt Creek from January 1, 2016, Through December 31, 2016	36
23	Dissolved Oxygen Concentration Measured Hourly at Wolf Road on Salt Creek from January 1, 2016, Through December 31, 2016	37

LIST OF ABBREVIATIONS

CAWS	Chicago Area Waterway System
CDOM	Continuous Dissolved Oxygen Monitoring
CRS	Chicago River System
District	Metropolitan Water Reclamation District of Greater Chicago
DO	dissolved oxygen
Eureka	Eureka Water Probes
IPCB	Illinois Pollution Control Board
M&R	Monitoring and Research
monitors	continuous water quality monitors
QAPP	Quality Assurance Project Plan
RR	railroad
SEPA	Sidestream Elevated Pool Aeration
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 approximate 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).

In 1998, the Monitoring and Research (M&R) 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.mwrdd.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, 2016, 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 2016 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 15 deep-draft CDOM monitoring stations in the CAWS. The deep-draft monitoring stations included two locations in the North Shore Channel, two locations in the North Branch Chicago River, one location in the Chicago River main stem, one location in the South Branch Chicago River, two locations in Bubbly Creek, three locations in the Chicago Sanitary and Ship Canal, two locations in the Little Calumet River, and two locations in the Calumet-Sag Channel.

There were seven CDOM stations in the Chicago Metropolitan Area Wadeable Streams. Five wadeable monitoring stations were located in the Upper Des Plaines River System. Two stations were on the Upper Des Plaines River and three stations were on Salt Creek. One wadeable monitoring station was in the Calumet River System on the Little Calumet River and one wadeable monitoring station was in the CRS on the North Branch of the Chicago River.

Three CDOM stations were added in 2016 that were not monitored in 2015. The station at Ogden Avenue was activated on March 18, 2016, the station at Church Street was activated on May 13, 2016, and the station at Central Park Avenue was activated on August 18, 2016.

Designated Uses for 2016

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 Little Calumet River are designated as General Use Waters. The North Shore Channel, North Branch Chicago River, South Branch Chicago River, Grand Calumet River, the deep-draft portion of the Little Calumet River, and the Calumet-Sag Channel are designated as CAWS Aquatic Life Use A Waters. The Chicago Sanitary and Ship Canal is designated as CAWS and Brandon Pool Aquatic Life Use B Waters.

Dissolved Oxygen Water Quality Standards for 2016

The IPCB has established water quality standards for DO. In Bubbly Creek, the DO shall not be less than 4.0 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

FIGURE 1: 2016 CONTINUOUS DISSOLVED OXYGEN MONITORING STATIONS

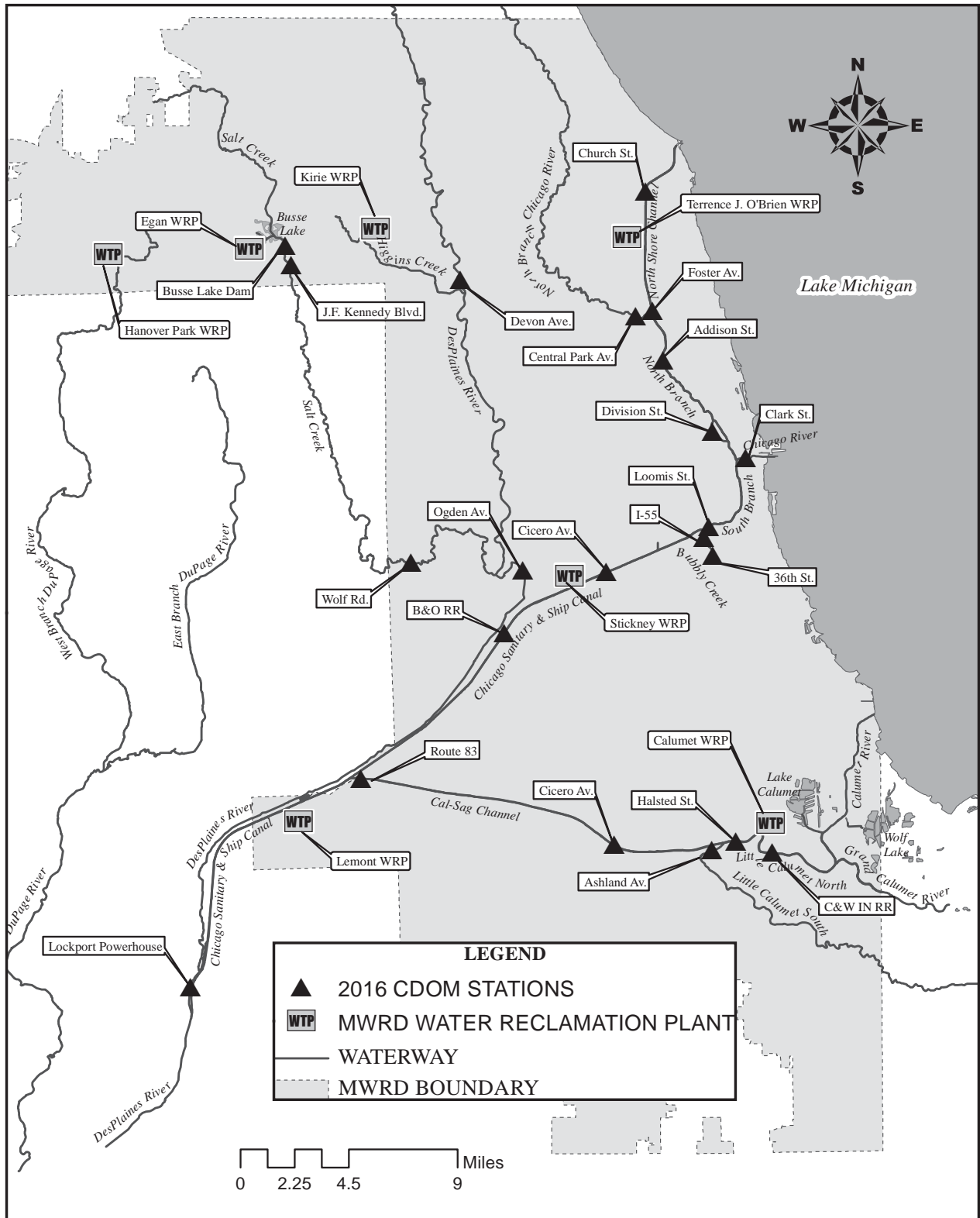


TABLE 1: CONTINUOUS DISSOLVED OXYGEN MONITORING STATIONS
DURING 2016

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.
Central Park Avenue	North Branch Chicago River	0.8 mile above junction with North Shore Channel, monitor on northeast side Central Park Avenue bridge, 2–4 inches from stream bed.
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.
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 2016

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 2016

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 2016

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 & 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.
J. F. Kennedy Boulevard	Salt Creek	0.8 mile below Egan WRP outfall, water quality monitor on southeast side of J. F. Kennedy Boulevard bridge, 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.

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.

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™ multi probe. In order to protect the monitors from marine navigation and vandalism, the monitors were deployed in the field in stainless steel, or 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 either the Winkler method or 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. Effective July 1, 2016, the QAPP was updated and the review process changed. The change was made following equipment upgrades of all of the monitors to newer, more accurate optical DO probes with self-cleaning wipers.

The review process prior to July 1, 2016, included the following:

1. Comparing a DO concentration measured in a laboratory holding tank and a DO concentration recorded by a monitor after retrieval from the field (DO rejection criteria = difference greater than 1.0 mg/L).
2. Comparing the last hourly DO concentration measured by the monitor retrieved in the field with the first hourly DO concentration recorded by the monitor that replaced it (DO rejection criteria = difference greater than 2.0 mg/L).
3. Comparing the grab sample DO concentration measured in the field with a DO concentration recorded by the respective monitor retrieved in the field (DO rejection criteria = difference greater than 2.0 mg/L).

Criterion 1 would entail rejection of all hourly readings; criteria 2 and 3 could result in rejection of all readings after careful review of the data. In the review process, any spikes in the data that could not be explained by factors such as weather conditions (temperature and rain events), specific conductivity, and flow data, were determined to be erroneous and therefore rejected. Any available upstream and downstream data were also reviewed to identify erroneous data, and the historical profile for a given monitoring station was also considered. Errors most often were attributed to fouling of the sensors or from sensor calibration drift. If the sensor fouling error was considered extensive, the entire deployment was rejected. Incidents of equipment failure also resulted in rejection of data. Only data that met the quality control criteria were used to compile results in this report.

The review process after July 1, 2016, included only the following two criteria:

4. 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).
5. 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 the absolute magnitude greater than 0.3 mg/L).

Criterion 4 would entail rejection of all hourly readings and criterion 5 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.

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 2016, 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 22 stations during 2016 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 2016 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 22 monitoring stations during 2016 are presented in Table 4.

Individual graphs showing hourly DO concentrations at each monitoring station are presented in Figures 2 through 23.

Summary statistics for DO measured during cross-sectional surveys are shown in Appendix A.

TABLE 2: MINIMUM, MAXIMUM, AND MEAN HOURLY DISSOLVED OXYGEN CONCENTRATIONS DURING 2016

Monitoring Station	Waterway	DO Concentration (mg/L)		
		Minimum	Maximum	Mean
-----Chicago River System-----				
Church Street	North Shore Channel	0.2	16.4	7.7
Foster Avenue	North Shore Channel	0.5	9.9	7.5
Central Park Avenue	North Branch Chicago River	3.2	14.7	8.5
Addison Street	North Branch Chicago River	2.1	12.1	7.6
Division Street	North Branch Chicago River	0.3	11.5	6.7
Clark Street	Chicago River	2.9	13.6	8.6
Loomis Street	South Branch Chicago River	0.3	12.1	6.8
36 th Street	Bubbly Creek	0.0	25.5	5.0
Interstate Highway 55	Bubbly Creek	0.0	20.7	4.0
Cicero Avenue	Chicago Sanitary and Ship Canal	0.1	11.4	5.8
B&O Central Railroad	Chicago Sanitary and Ship Canal	0.4	11.0	6.4
Lockport Powerhouse	Chicago Sanitary and Ship Canal	0.2	10.3	5.3
-----Calumet River System-----				
C&W Indiana Railroad	Little Calumet River	2.9	14.0	9.8
Halsted Street	Little Calumet River	2.0	12.3	7.9
Ashland Avenue	Little Calumet River	2.4	28.5	8.9
Cicero Avenue	Calumet-Sag Channel	3.2	13.4	7.5
Route 83	Calumet-Sag Channel	2.5	13.3	7.1
-----Des Plaines River System-----				
Devon Avenue	Des Plaines River	3.5	14.6	8.8
Ogden Avenue	Des Plaines River	4.1	14.2	8.6
Busse Lake Dam	Salt Creek	0.0	15.1	10.1
J.F. Kennedy Boulevard	Salt Creek	0.3	13.9	8.4
Wolf Road	Salt Creek	0.1	19.9	9.2

TABLE 3: NUMBER AND PERCENT OF DISSOLVED OXYGEN VALUES NOT MEETING ACCEPTANCE CRITERIA DURING 2016

Monitoring Station	Waterway	Number of DO Values Rejected	Percent of DO Values Rejected
-----Chicago River System-----			
Church Street	North Shore Channel	0	0
Foster Avenue	North Shore Channel	1,527	17 ^a
Central Park Avenue	North Branch Chicago River	0	0
Addison Street	North Branch Chicago River	505	6 ^b
Division Street	North Branch Chicago River	0	0
Clark Street	Chicago River	0	0
Loomis Street	South Branch Chicago River	502	6 ^c
36 th Street	Bubbly Creek	1,536	18 ^d
Interstate Highway 55	Bubbly Creek	1,812	21 ^e
Cicero Avenue	Chicago Sanitary and Ship Canal	506	6 ^f
B&O Central Railroad	Chicago Sanitary and Ship Canal	1,485	17 ^g
Lockport Powerhouse	Chicago Sanitary and Ship Canal	0	0
-----Calumet River System-----			
C&W Indiana Railroad	Little Calumet River	1,463	17 ^h
Halsted Street	Little Calumet River	3,840	44 ⁱ
Ashland Avenue	Little Calumet River	1,755	20 ^j
Cicero Avenue	Calumet-Sag Channel	0	0
Route 83	Calumet-Sag Channel	1,035	12 ^k
-----Des Plaines River System-----			
Devon Avenue	Des Plaines River	0	0
Ogden Avenue	Des Plaines River	1,569	23 ^l
Busse Lake Dam	Salt Creek	2,041	23 ^m
J.F. Kennedy Boulevard	Salt Creek	505	6 ⁿ
Wolf Road	Salt Creek	0	0

^a2/19 – 3/10/16, 3/10 – 3/31/16 monitor failed criteria 2 and 3, 12/9 – 12/31/16 monitor failed criterion 4.

^b9/13 – 10/4/16 monitor failed criterion 4.

^c8/9 – 8/30/16 monitor failed criterion 5.

^d3/30 - 4/20/16 monitor failed criteria 2 and 3, 7/12 – 8/3/16 monitor failed criterion 5, 9/14 – 10/5/16 monitor failed criteria 4 and 5.

^e1/1 – 1/12/16 monitor failed criteria 2 and 3, 8/30 – 9/21/16 monitor failed criteria 4 and 5, 9/21 -10/11/16, 11/1 – 11/23/16 monitor failed criterion 5.

^f8/9 – 8/30/16 monitor failed criterion 4.

TABLE 3 (Continued): NUMBER AND PERCENT OF DISSOLVED OXYGEN VALUES NOT MEETING ACCEPTANCE CRITERIA DURING 2016

- ^g5/19 – 6/9/16 monitor failed criteria 2 and 3, 8/9 - 8/30/16, 9/21 – 10/11/16 monitor failed criterion 5.
- ^h3/24 – 4/13/16 equipment failure, 7/7 – 7/26/16 monitor failed criterion 5, 7/26 – 8/17/16 monitor failed criteria 4 and 5.
- ⁱ2/9 – 3/3/16, 8/17 – 8/29/16 equipment failure. 4/13 – 5/3/16 monitor failed criteria 2 and 3. 6/14 – 7/7/16, 7/7 – 7/26/16, 7/26 – 8/17/16, 9/8 – 9/28/16, 9/28 – 10/19/16 monitor failed criterion 5.
- ^j5/4 – 5/27/16 monitor failed criteria 2 and 3. 7/27 – 8/16/16 equipment failure. 10/18 – 11/16/16 monitor failed criterion 5.
- ^k3/1 – 3/24/16, 3/24 – 4/13/16 equipment failure.
- ^l5/18 – 6/8/16 monitor failed criteria 2 and 3. 6/8 – 7/19/16, 12/28 – 12/31/16 equipment failure.
- ^m5/18 – 6/8/16, 6/8 – 6/30/16 monitor failed criteria 2 and 3. 7/19 – 8/10/16, 8/31 – 9/20/16 monitor failed criterion 5.
- ⁿ4/27 – 5/18/16, equipment failure.

TABLE 4: PERCENT OF DISSOLVED OXYGEN VALUES IN SELECTED RANGES DURING 2016

Monitoring Station	Waterway	Percent of DO 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	<1	2	3	2	6	9	14	20	17	11	17
Foster Avenue	North Shore Channel	<1	0	<1	<1	<1	3	23	48	24	2	0
Central Park Avenue	North Branch Chicago River	0	0	0	<1	<1	10	22	18	20	5	26
Addison Street	North Branch Chicago River	0	0	<1	<1	1	9	27	23	25	11	4
Division Street	North Branch Chicago River	<1	<1	<1	2	8	27	19	20	16	5	2
Clark Street	Chicago river	0	0	<1	<1	<1	2	9	31	24	17	18
Loomis Street	South Branch Chicago River	<1	<1	<1	2	11	23	22	14	12	7	7
36 th Street	Bubbly Creek	41	6	4	5	6	4	6	6	3	2	17
Interstate Highway 55	Bubbly Creek	35	8	8	5	3	9	9	7	4	2	9
Cicero Avenue	Chicago Sanitary and Ship Canal	4	5	11	9	11	11	11	15	9	8	6
B&O Central Railroad	Chicago Sanitary and Ship Canal	<1	<1	4	10	12	13	14	21	15	9	1
Lockport Powerhouse	Chicago Sanitary and Ship Canal	3	8	11	16	10	11	12	8	11	11	<1
-----Calumet River System-----												
C&W Indiana Railroad	Little Calumet River	0	0	<1	<1	3	4	7	14	14	10	47
Halsted Street	Little Calumet River	0	<1	<1	1	4	8	17	22	19	23	7
Ashland Avenue	Little Calumet River	0	0	<1	3	10	14	8	6	6	10	43
Cicero Avenue	Calumet-Sag Channel	0	0	0	<1	5	18	24	16	10	13	14
Route 83	Calumet-Sag Channel	0	0	<1	5	12	23	17	7	9	9	17
-----Des Plaines River System-----												
Devon Avenue	Des Plaines River	0	0	0	<1	7	12	13	11	11	9	38
Ogden Avenue	Des Plaines River	0	0	0	0	4	12	10	16	19	10	30
Busse Lake Dam	Salt Creek	1	<1	<1	1	2	4	5	8	10	10	57
J.F. Kennedy Boulevard	Salt Creek	1	<1	<1	<1	1	8	16	15	13	17	27
Wolf Road	Salt Creek	<1	<1	<1	<1	<1	6	19	12	13	12	38

^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 MAY 13, 2016, THROUGH DECEMBER 31, 2016

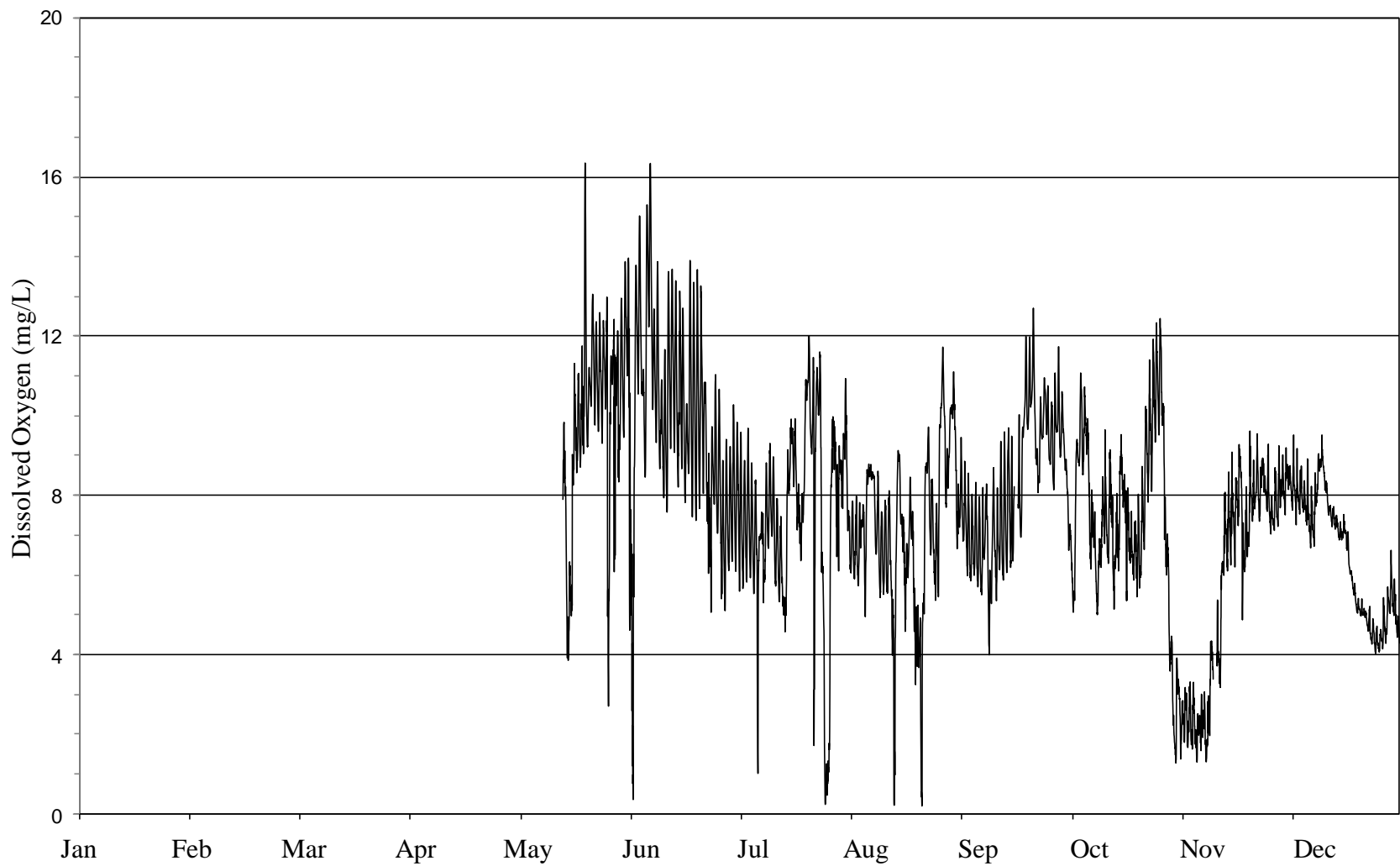


FIGURE 3: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT FOSTER AVENUE ON THE NORTH SHORE CHANNEL FROM JANUARY 1, 2016, THROUGH DECEMBER 31, 2016

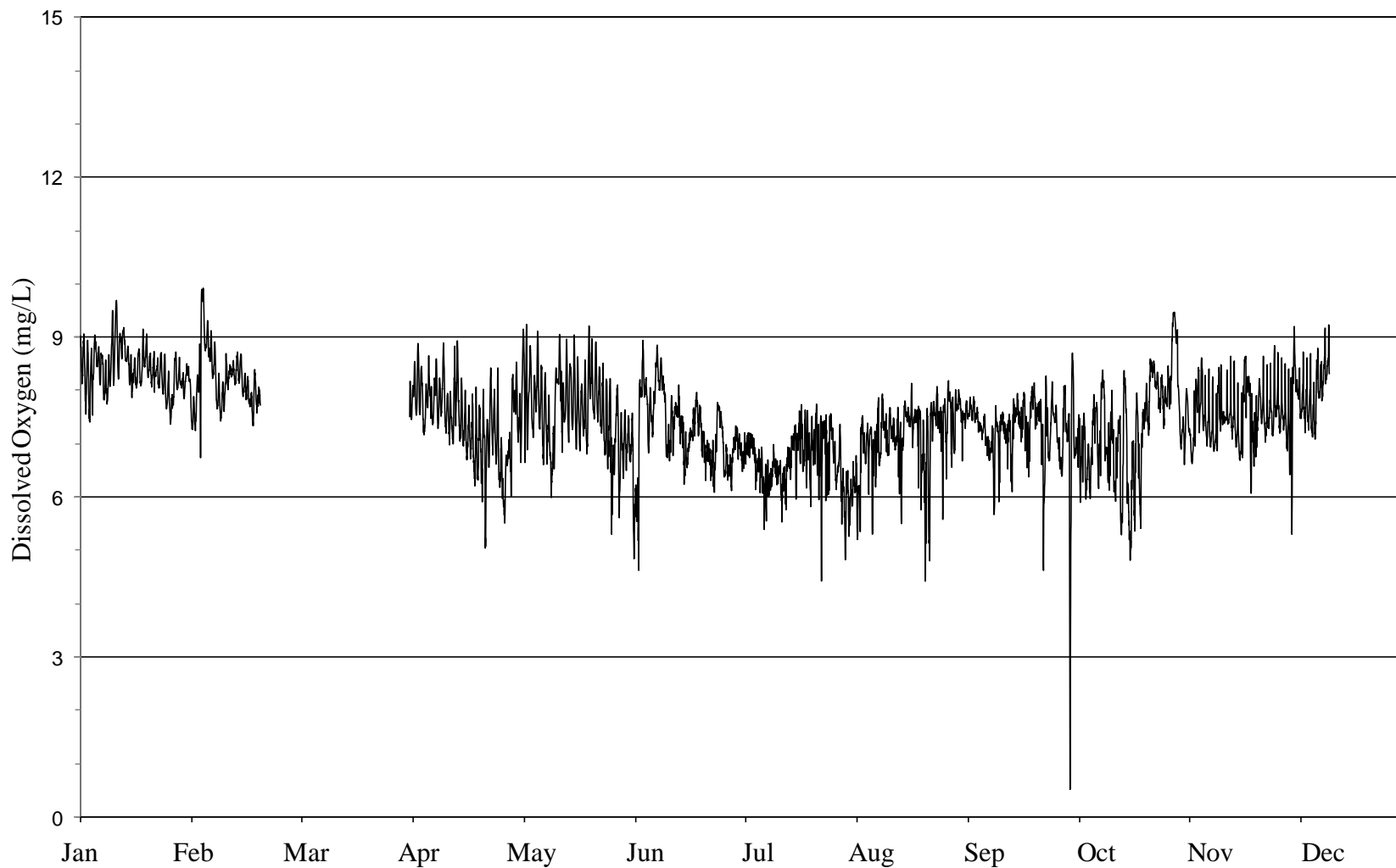


FIGURE 4: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT CENTRAL PARK AVENUE ON THE NORTH BRANCH CHICAGO RIVER FROM AUGUST 18, 2016, THROUGH DECEMBER 31, 2016



FIGURE 5: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT ADDISON STREET ON THE NORTH BRANCH CHICAGO RIVER FROM JANUARY 1, 2016, THROUGH DECEMBER 31, 2016

61

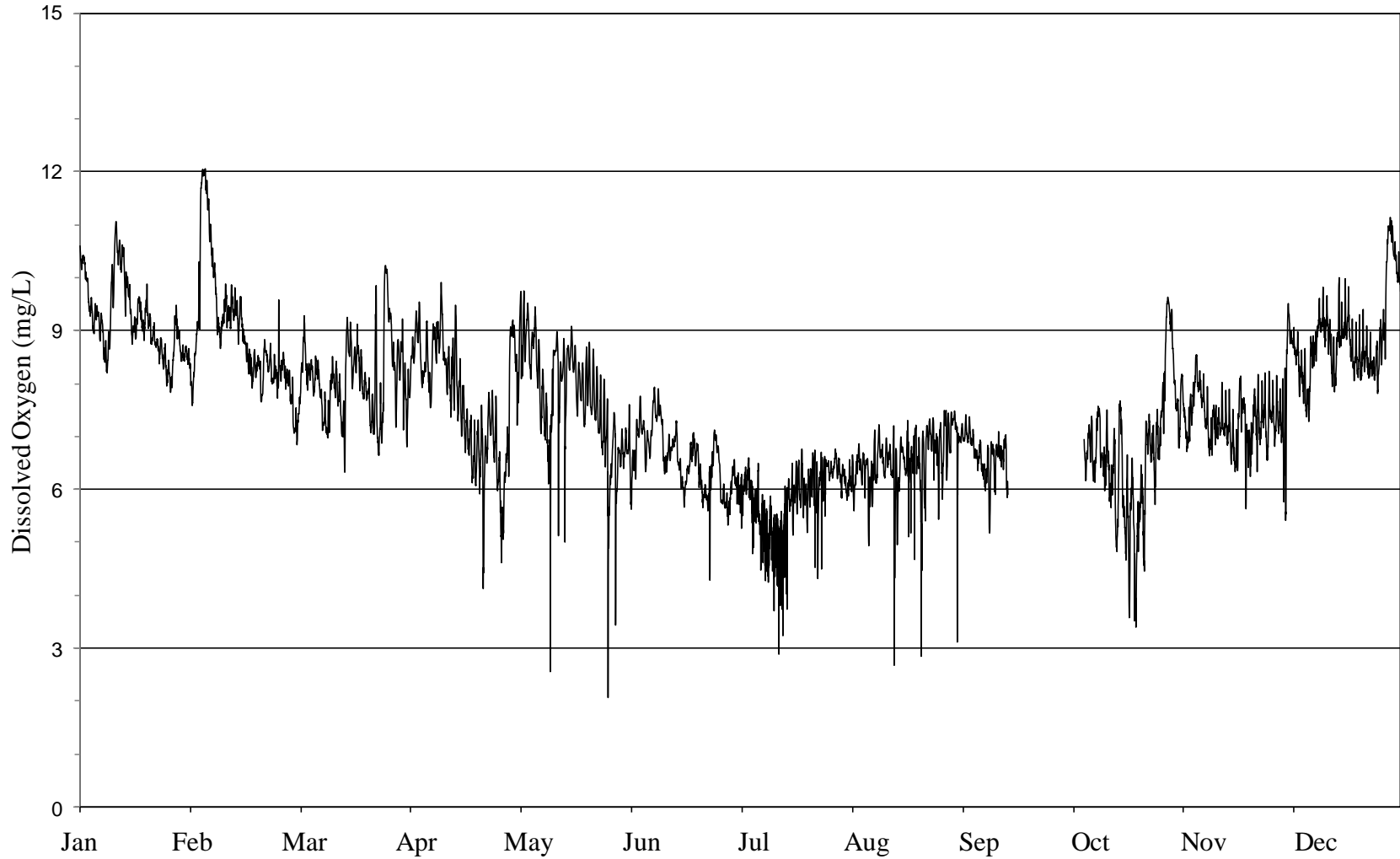


FIGURE 6: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT DIVISION STREET ON THE NORTH BRANCH CHICAGO RIVER FROM JANUARY 1, 2016, THROUGH DECEMBER 31, 2016

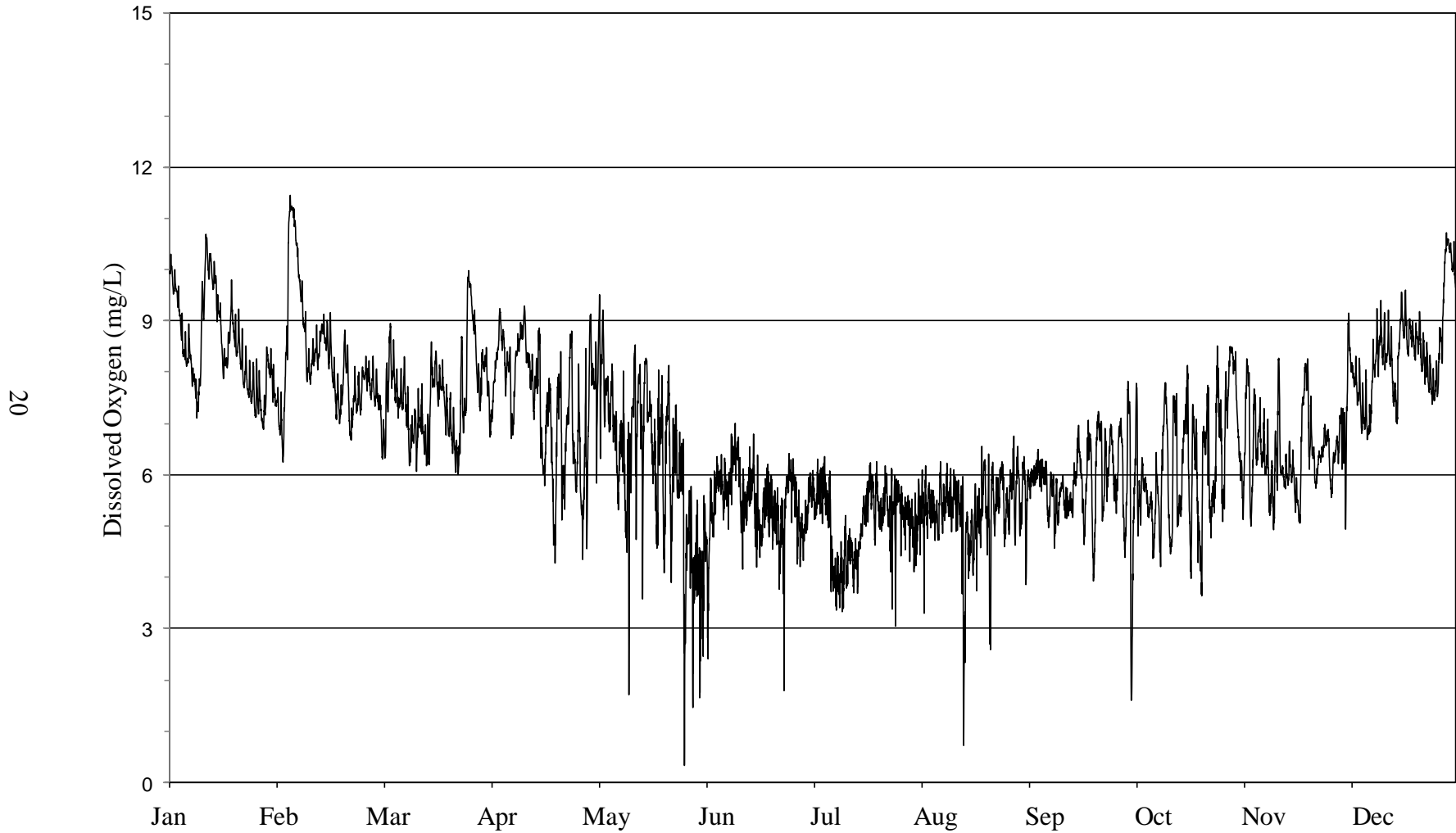


FIGURE 7: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT CLARK STREET ON THE CHICAGO RIVER FROM JANUARY 1, 2016, THROUGH DECEMBER 31, 2016

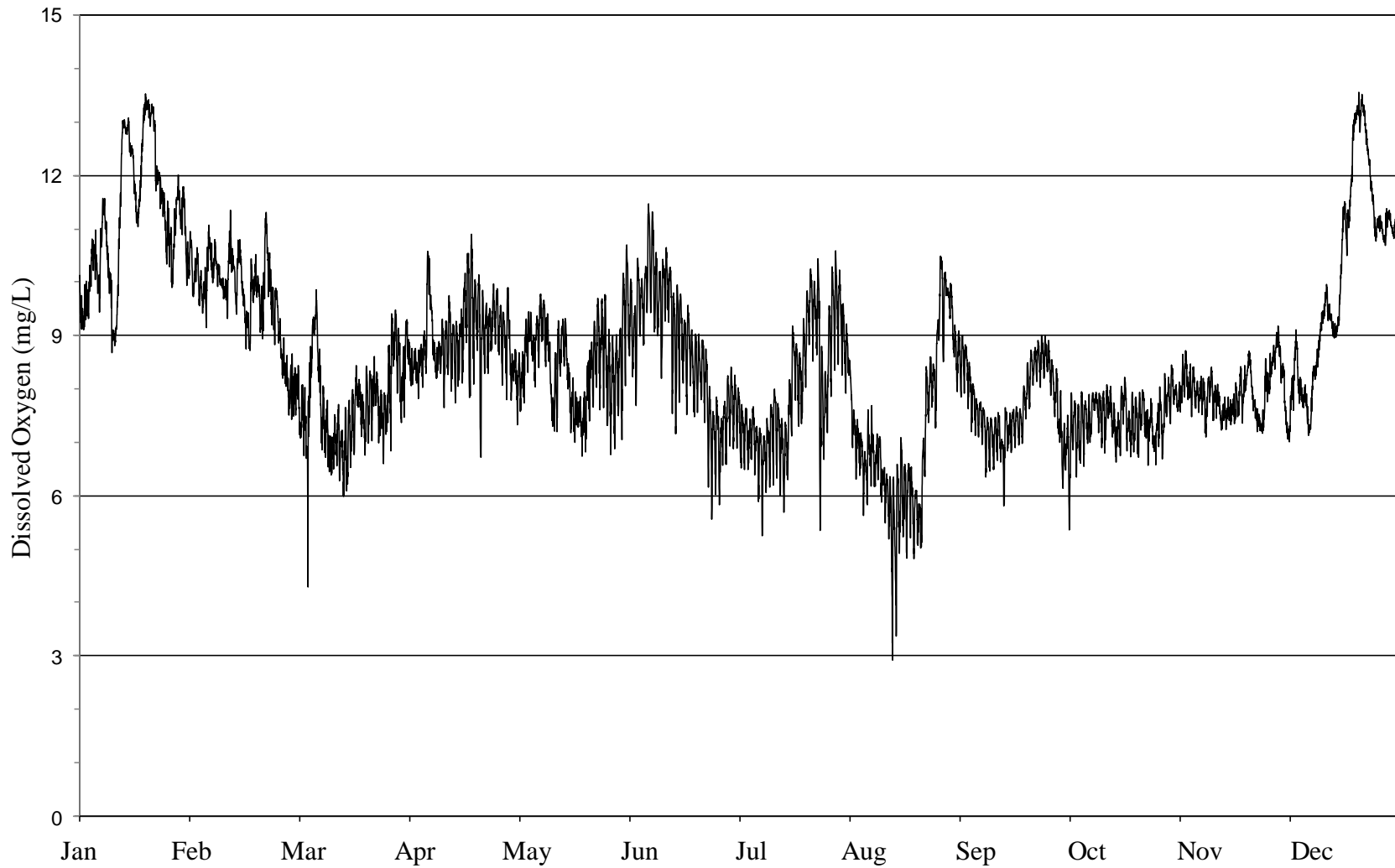


FIGURE 8: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT LOOMIS STREET ON THE SOUTH BRANCH CHICAGO RIVER FROM JANUARY 1, 2016, THROUGH DECEMBER 31, 2016

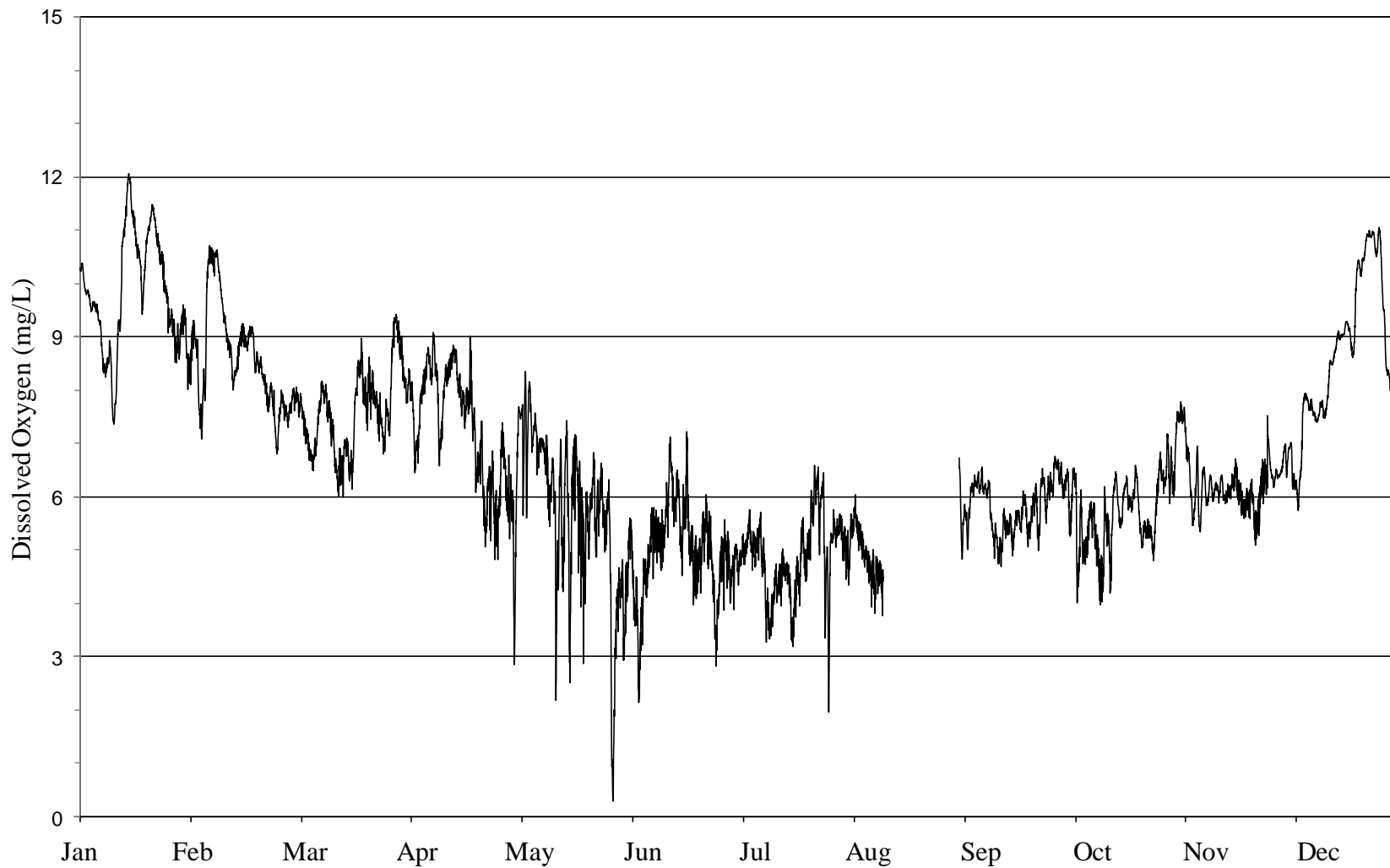


FIGURE 9: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT 36TH STREET ON BUBBLY CREEK FROM JANUARY 1, 2016, THROUGH DECEMBER 31, 2016

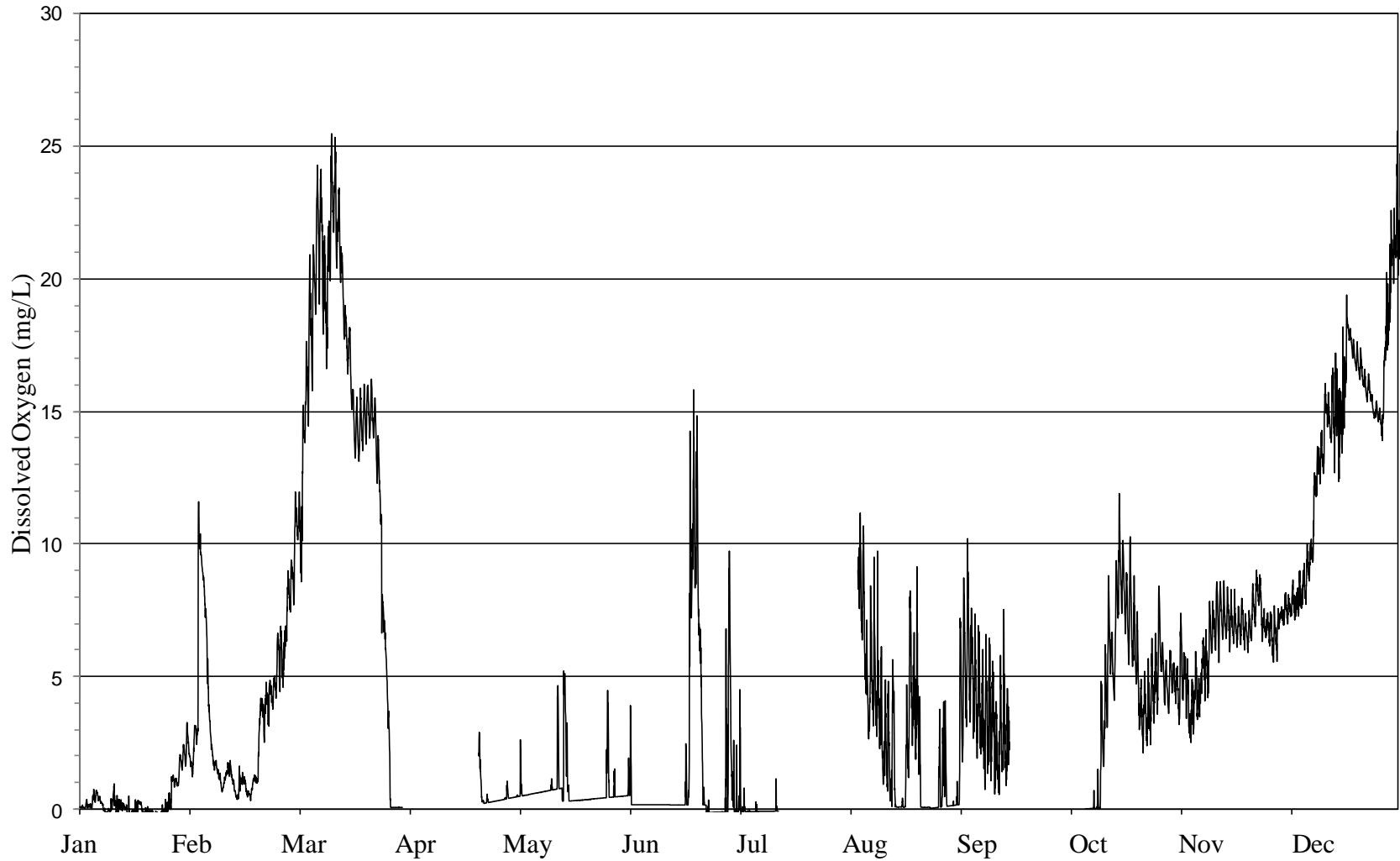


FIGURE 10: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT INTERSTATE HIGHWAY 55 ON BUBBLY CREEK FROM JANUARY 1, 2016, THROUGH DECEMBER 31, 2016

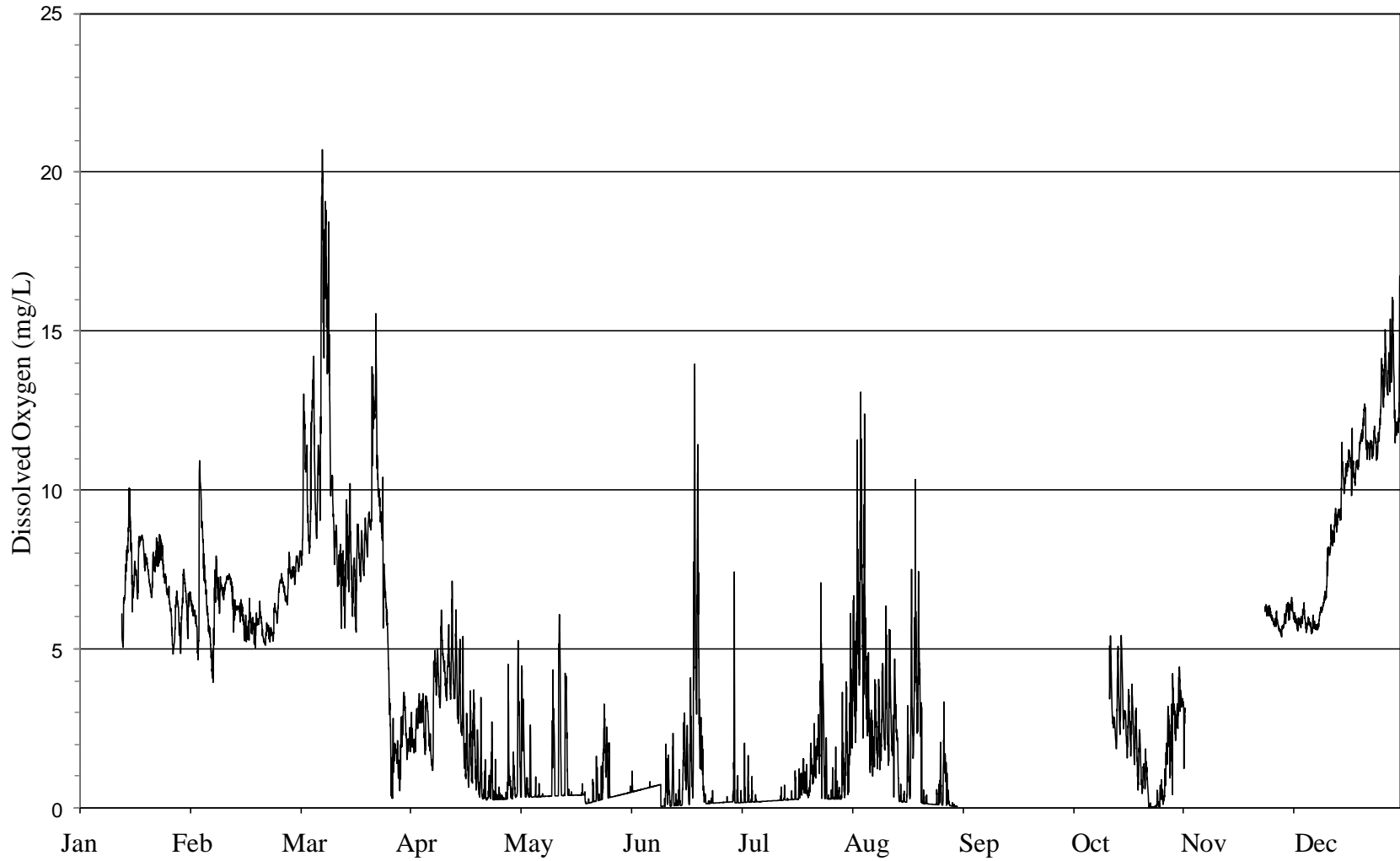


FIGURE 11: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT CICERO AVENUE ON THE CHICAGO SANITARY AND SHIP CANAL FROM JANUARY 1, 2016, THROUGH DECEMBER 31, 2016

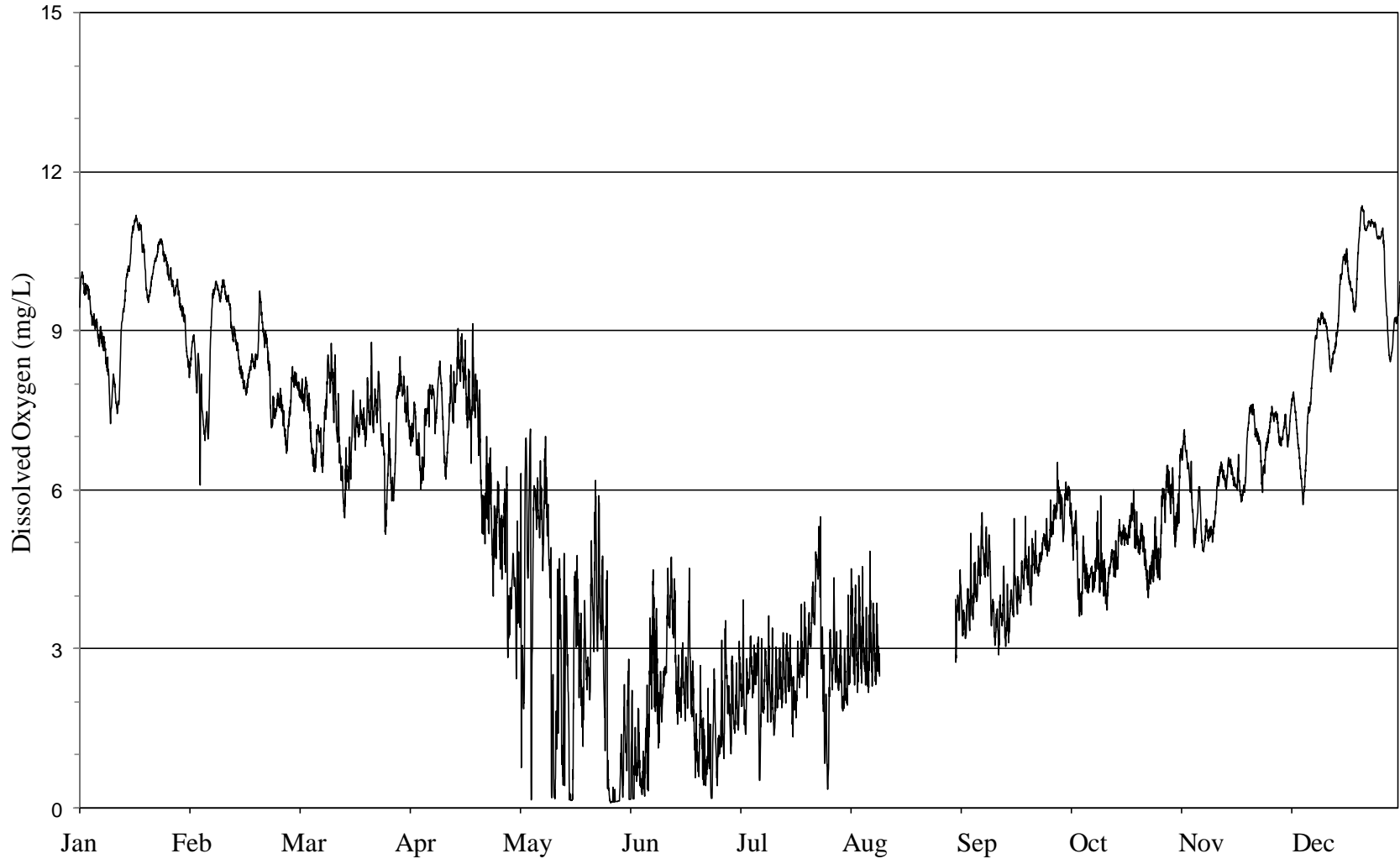


FIGURE 12: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT B&O CENTRAL RAILROAD ON THE CHICAGO SANITARY AND SHIP CANAL FROM JANUARY 1, 2016, THROUGH DECEMBER 31, 2016

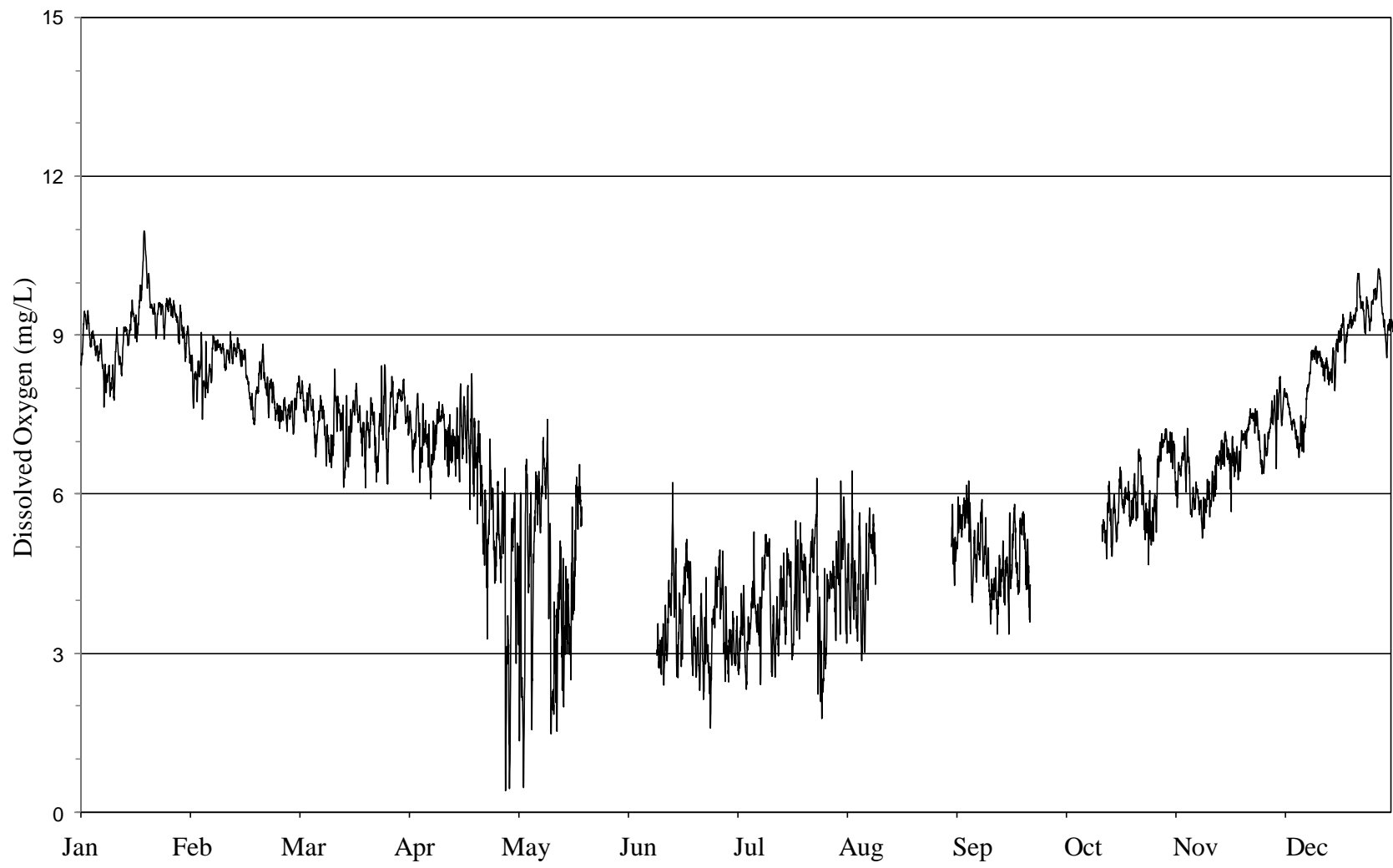


FIGURE 13: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT LOCKPORT POWERHOUSE ON THE CHICAGO SANITARY AND SHIP CANAL FROM JANUARY 1, 2016, THROUGH DECEMBER 31, 2016

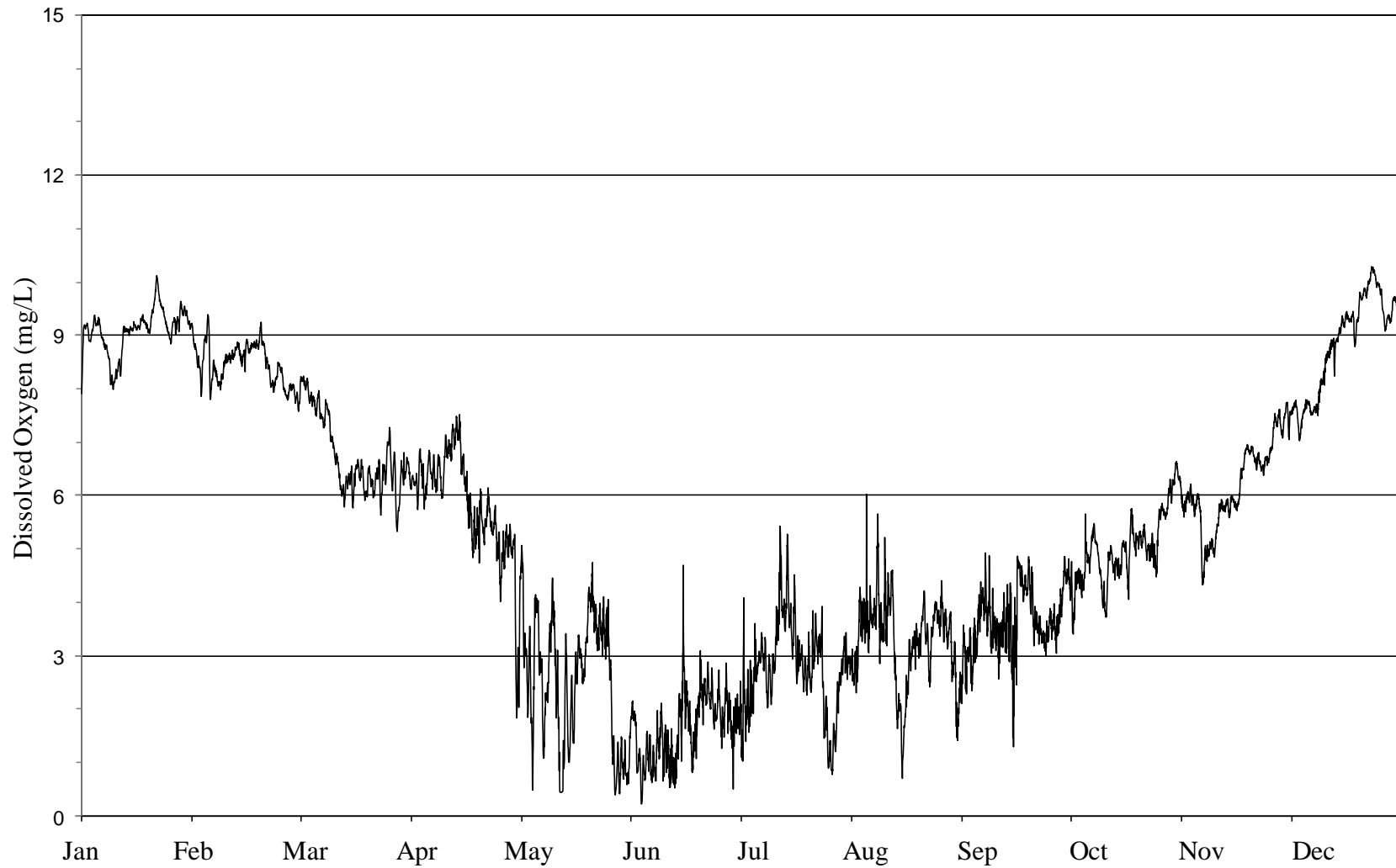


FIGURE 14: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT C&W INDIANA RAILROAD ON THE LITTLE CALUMET RIVER FROM JANUARY 1, 2016, THROUGH DECEMBER 31, 2016

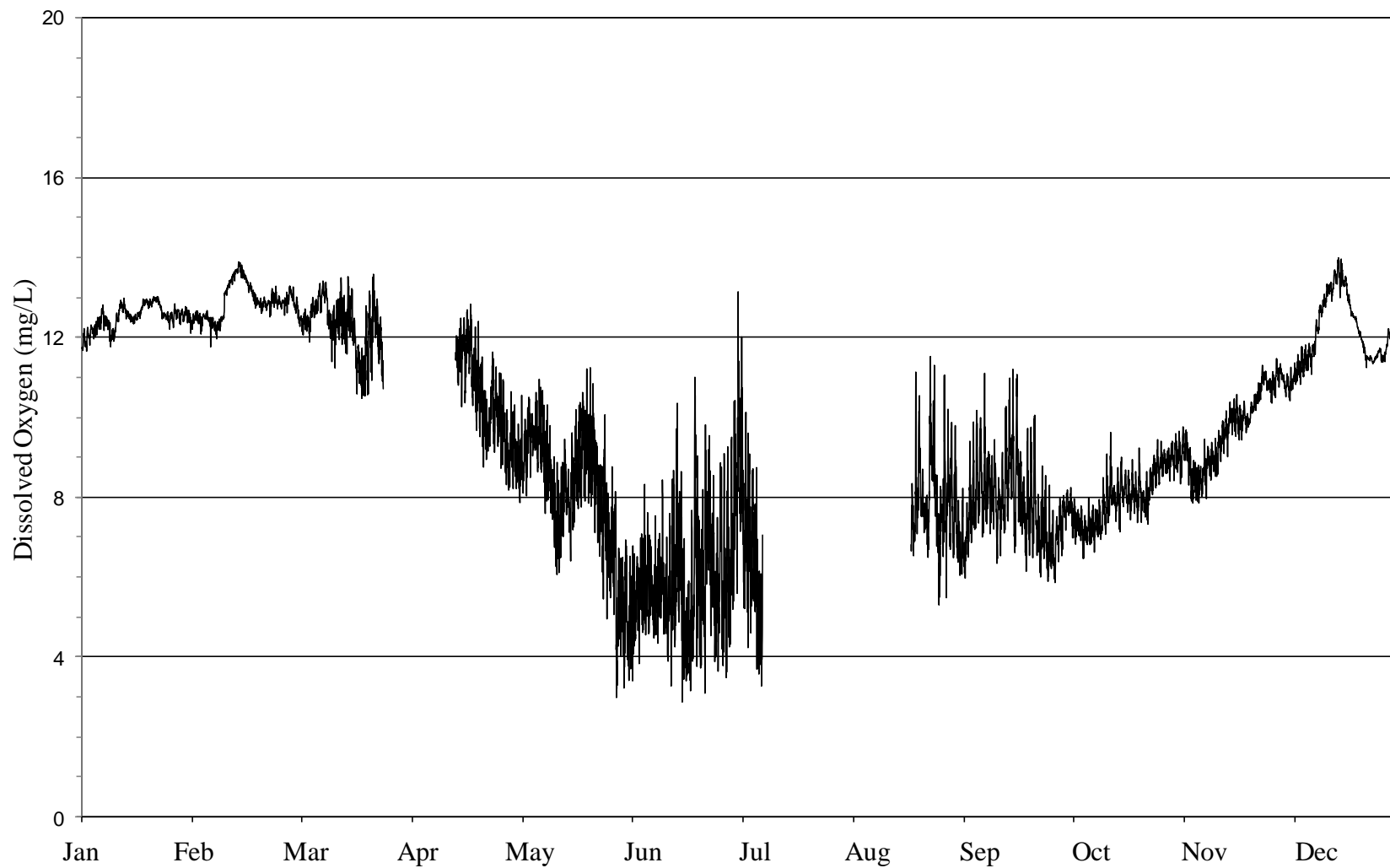


FIGURE 15: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT HALSTED STREET ON THE LITTLE CALUMET RIVER FROM JANUARY 1, 2016, THROUGH DECEMBER 31, 2016

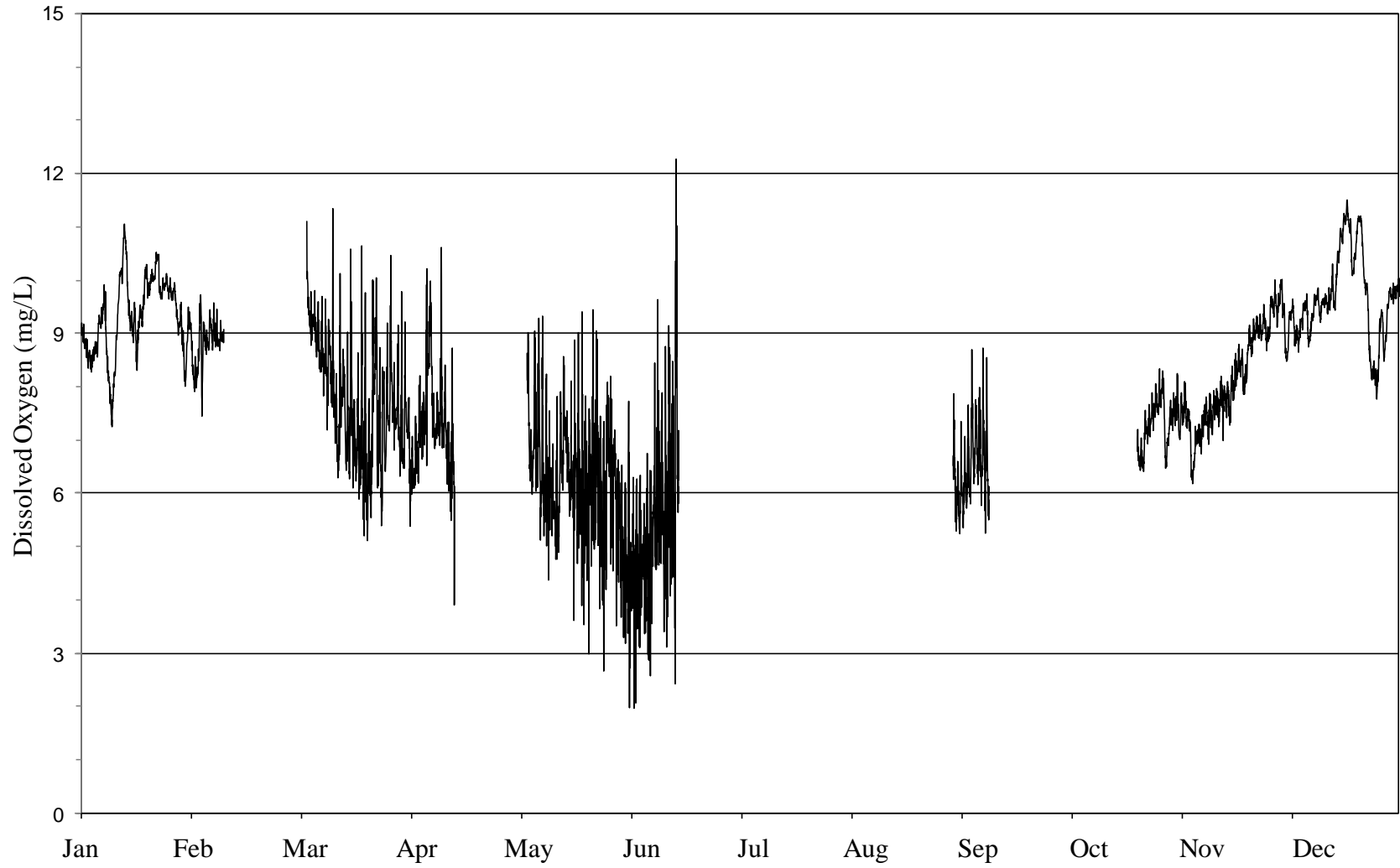


FIGURE 16: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT ASHLAND AVENUE ON THE LITTLE CALUMET RIVER FROM JANUARY 1, 2016, THROUGH DECEMBER 31, 2016

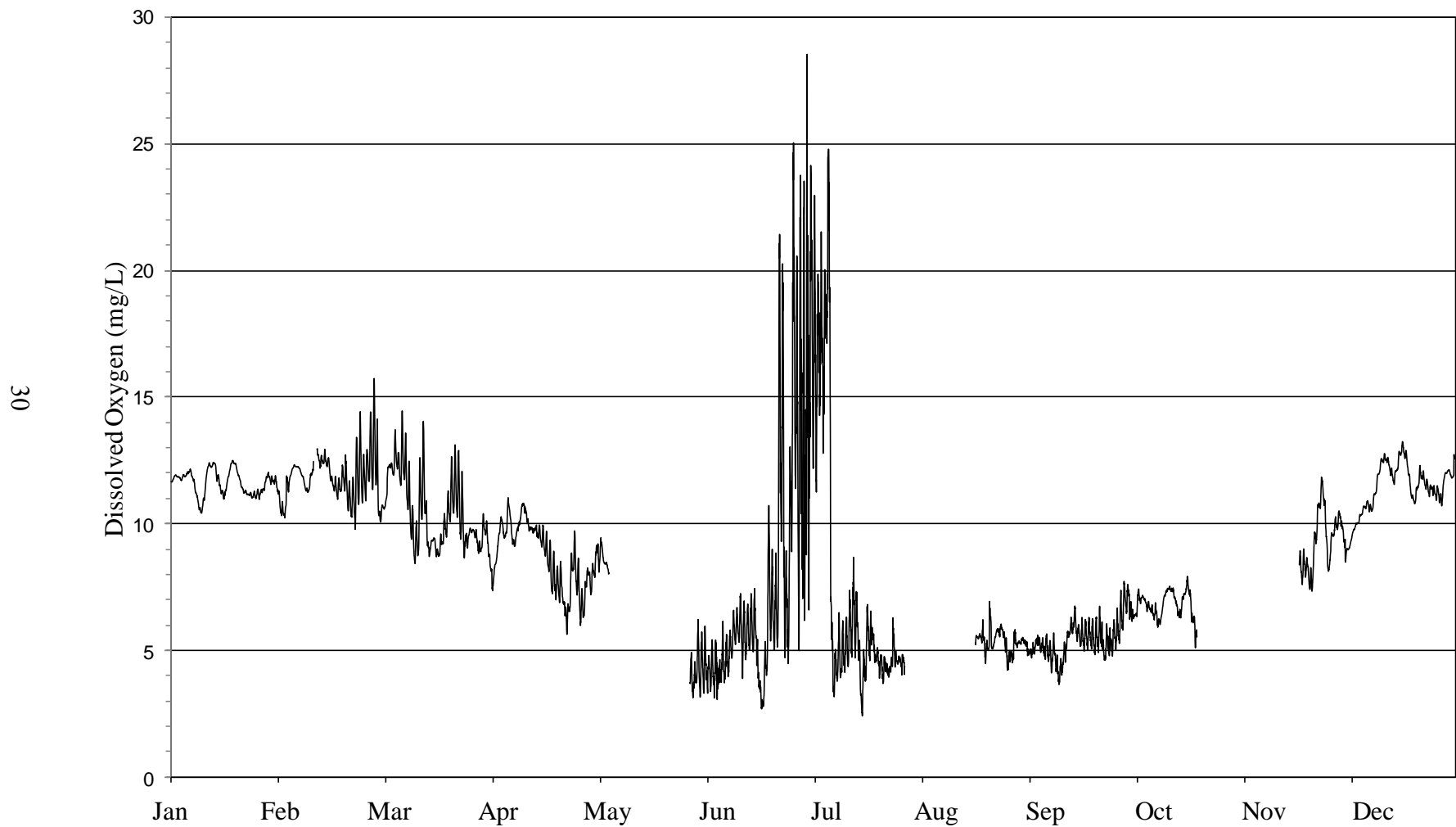


FIGURE 17: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT CICERO AVENUE ON THE CALUMET-SAG CHANNEL FROM JANUARY 1, 2016, THROUGH DECEMBER 31, 2016

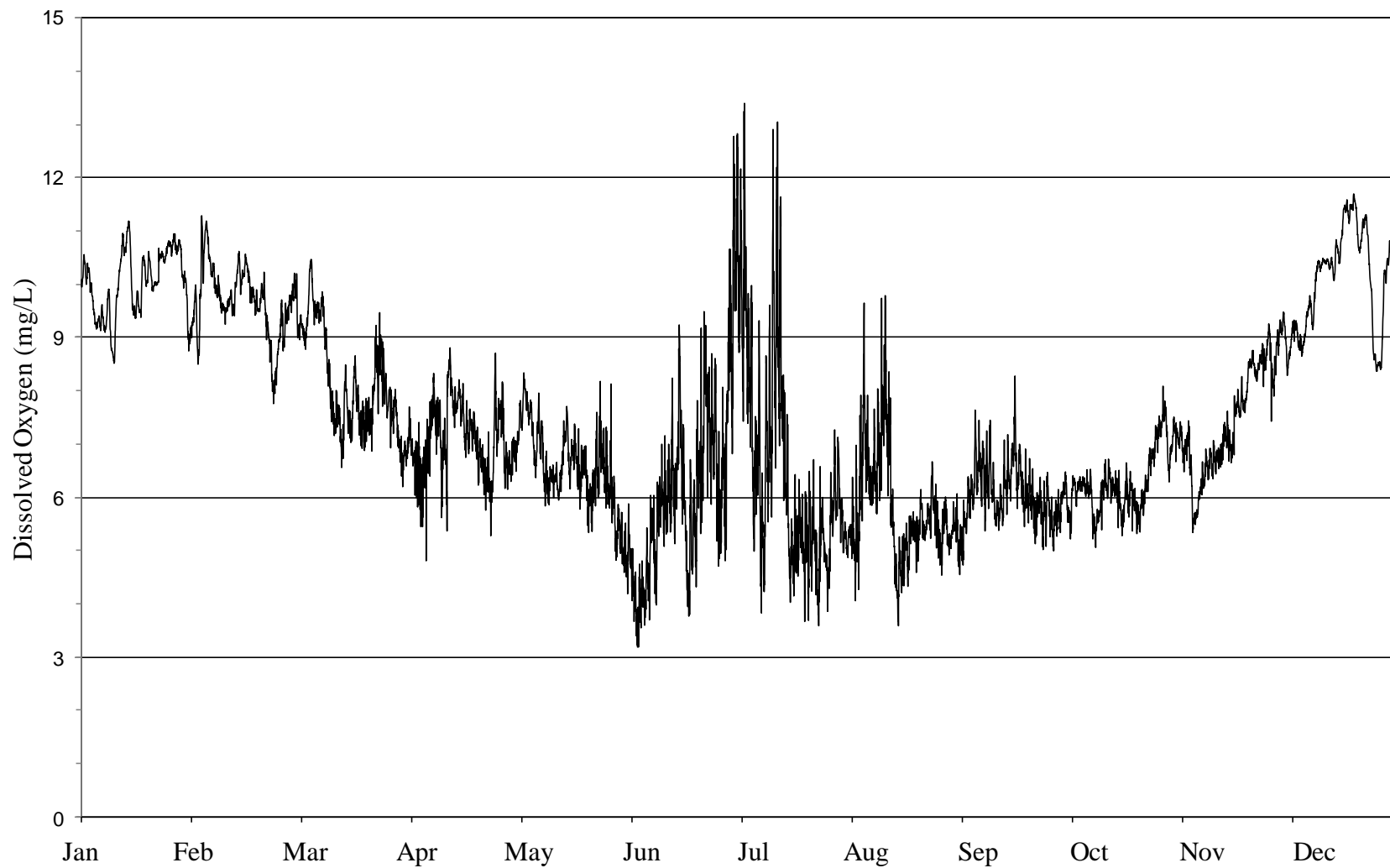


FIGURE 18: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT ROUTE 83 ON THE CALUMET-SAG CHANNEL FROM JANUARY 1, 2016, THROUGH DECEMBER 31, 2016

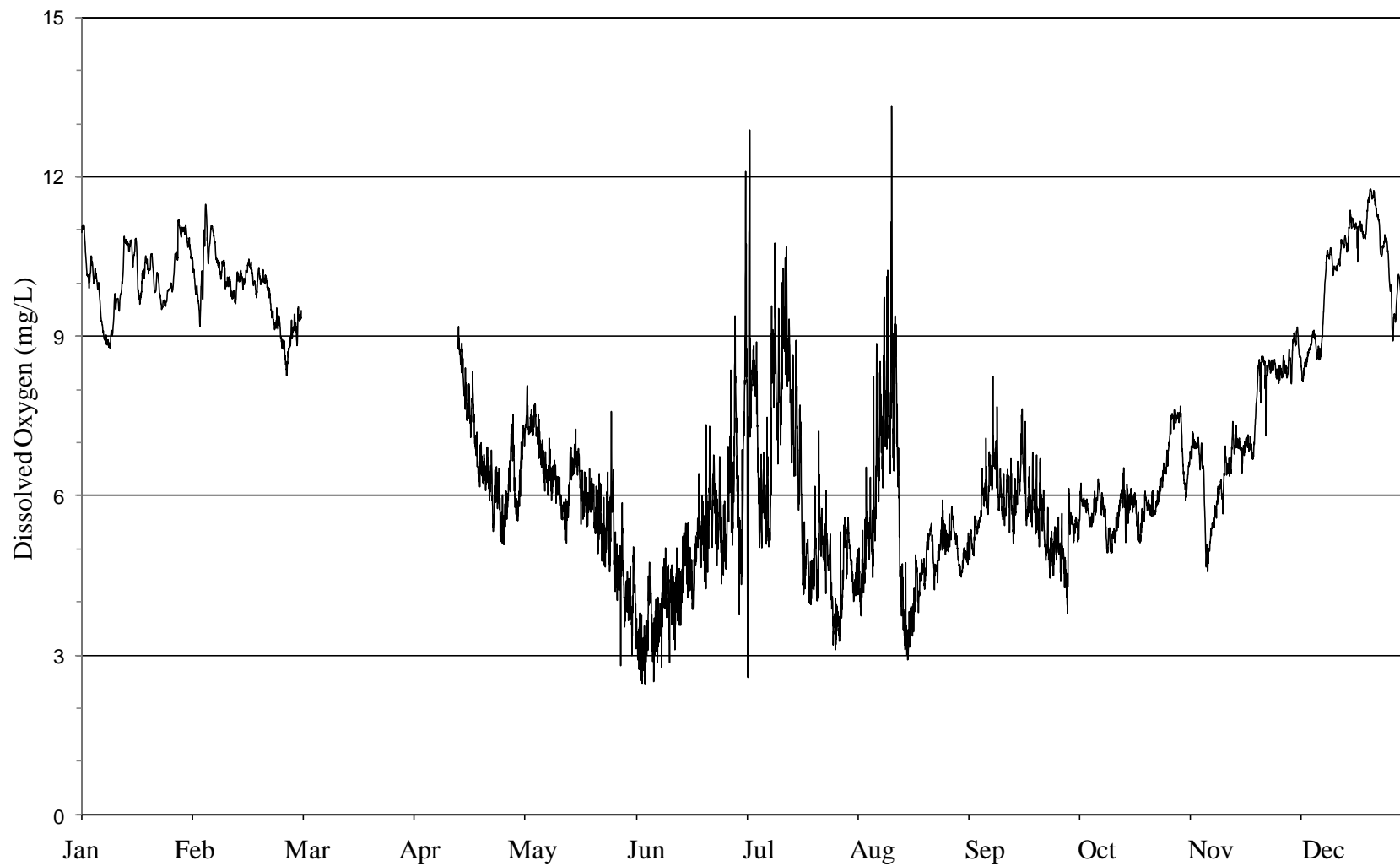


FIGURE 19: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT DEVON AVENUE ON THE DES PLAINES RIVER FROM JANUARY 1, 2016, THROUGH DECEMBER 31, 2016



FIGURE 20: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT OGDEN AVENUE ON THE DES PLAINES RIVER FROM MARCH 18, 2016, THROUGH DECEMBER 31, 2016

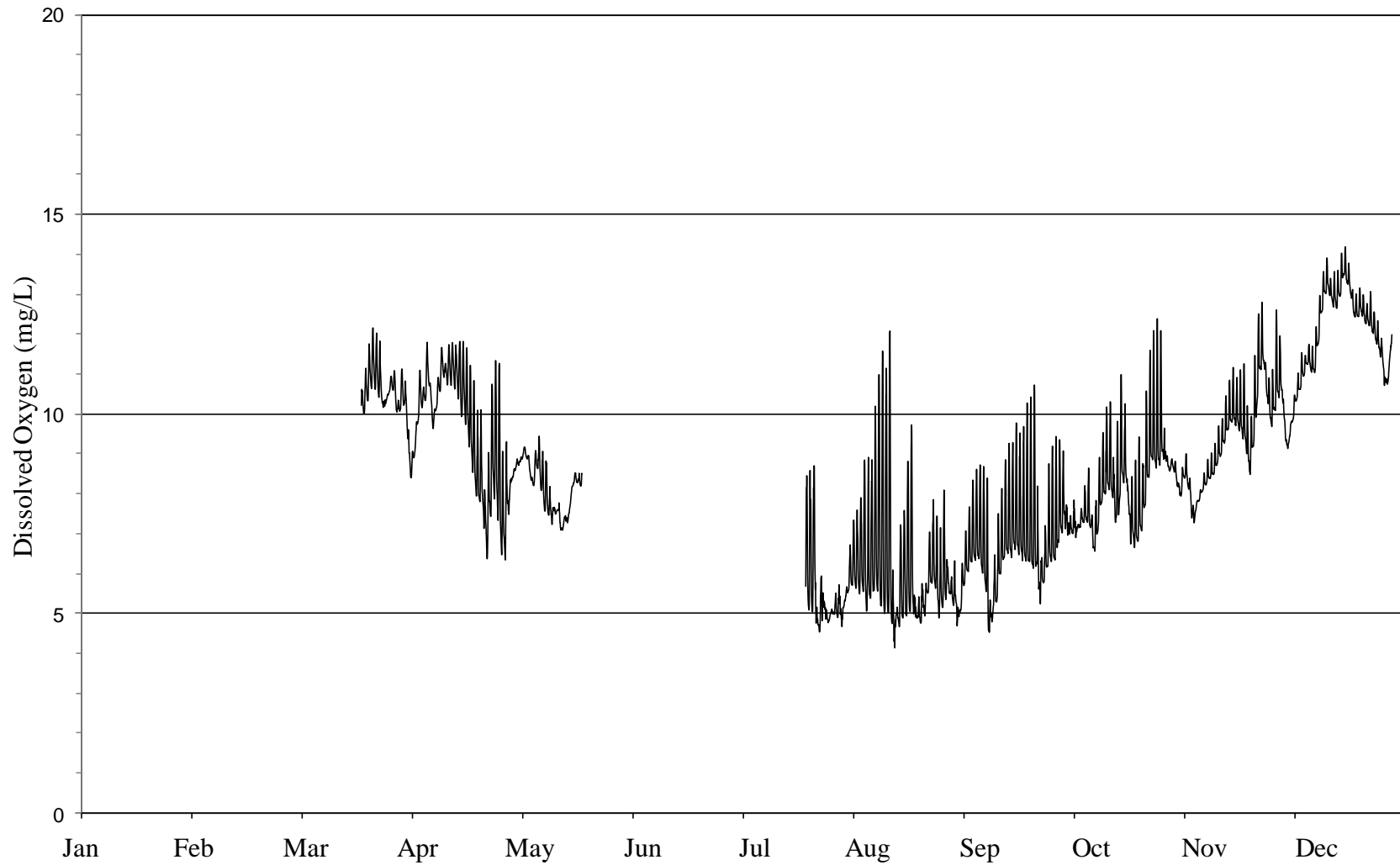


FIGURE 21: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT BUSSE LAKE DAM ON SALT CREEK FROM JANUARY 1, 2016, THROUGH DECEMBER 31, 2016

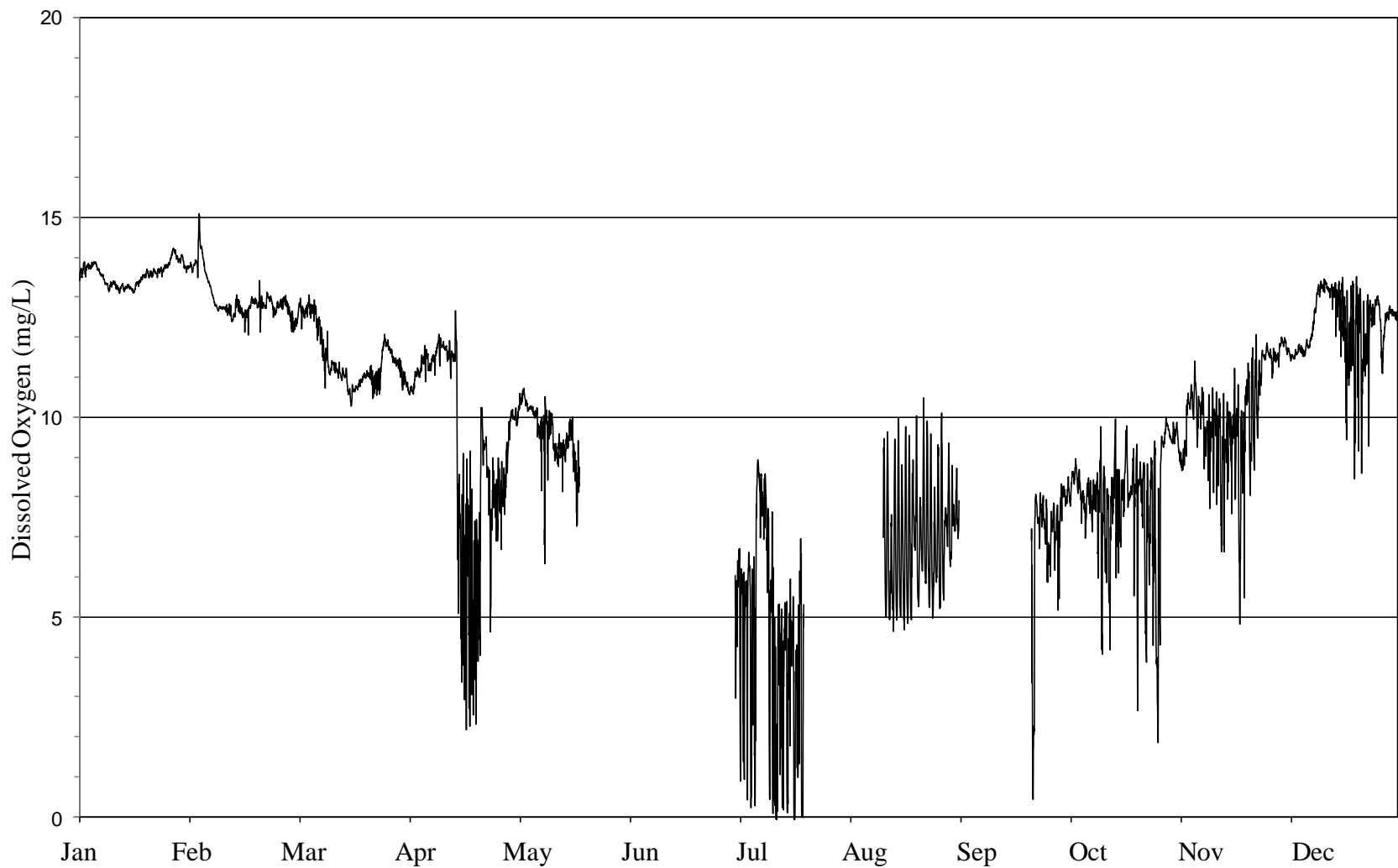


FIGURE 22: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT J.F. KENNEDY BOULEVARD ON SALT CREEK FROM JANUARY 1, 2016, THROUGH DECEMBER 31, 2016

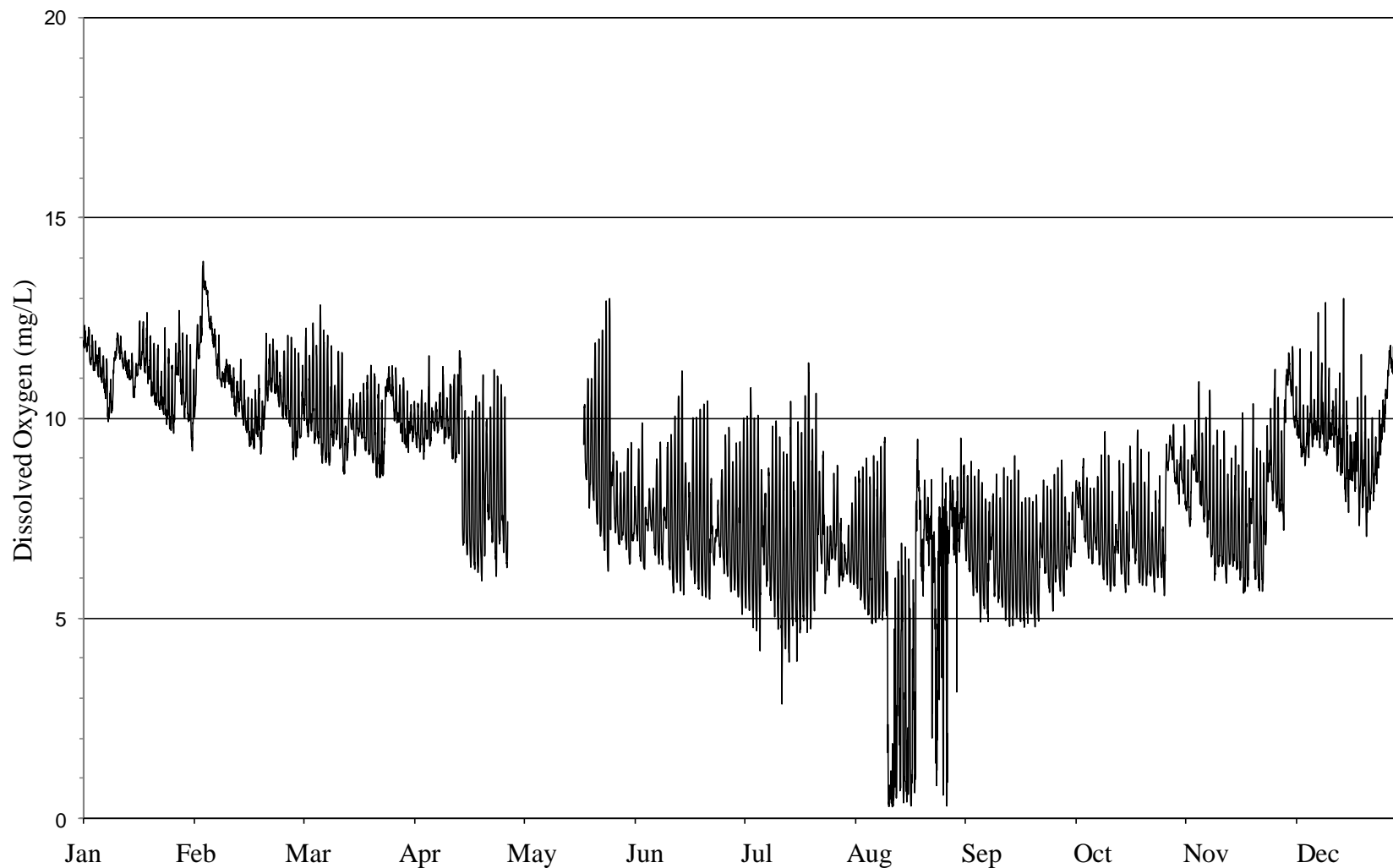
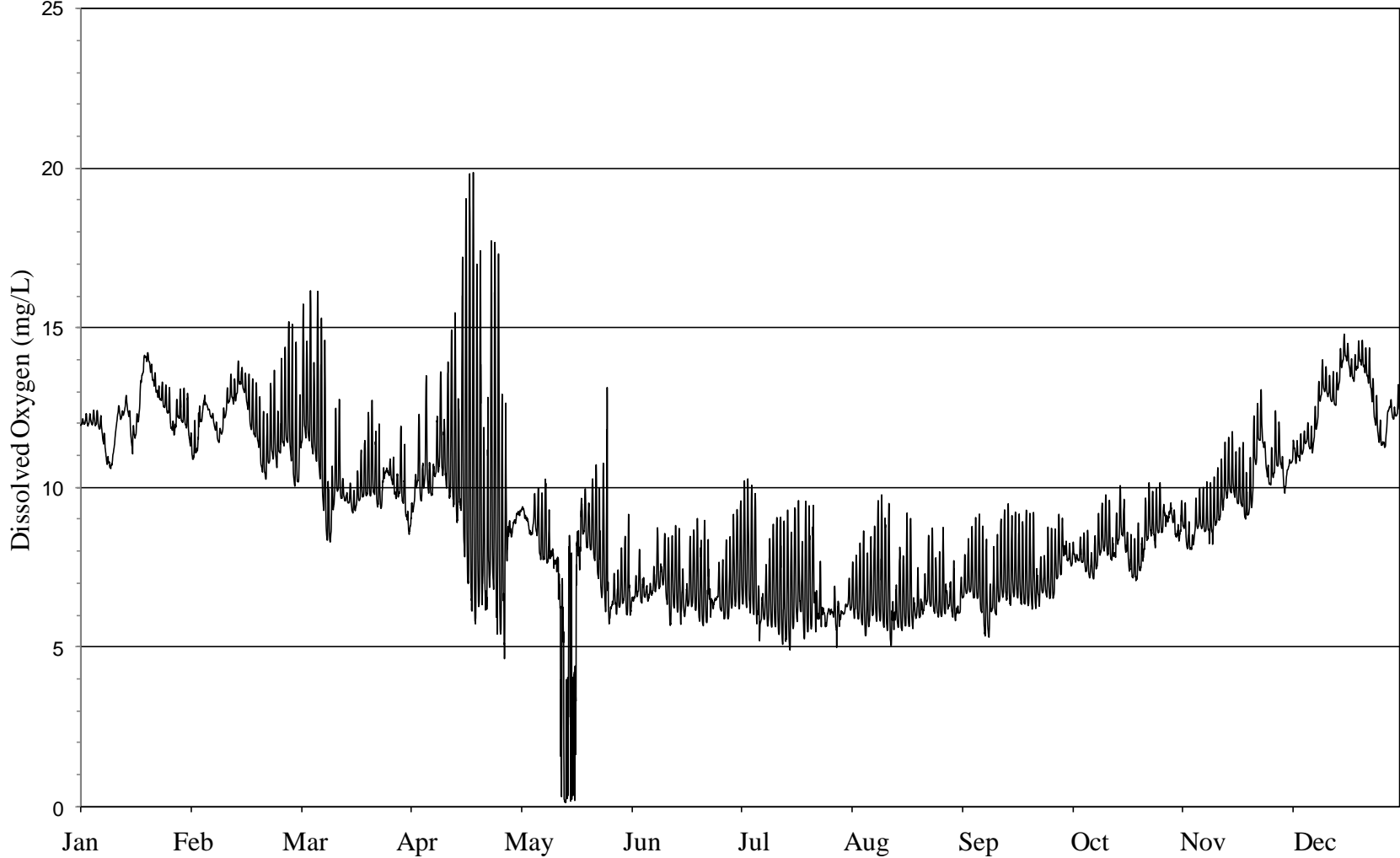


FIGURE 23: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT WOLF ROAD ON SALT CREEK FROM JANUARY 1, 2016, THROUGH DECEMBER 31, 2016



REFERENCES

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 A

SUMMARY STATISTICS FOR DISSOLVED OXYGEN MEASURED DURING
CROSS-SECTIONAL SURVEYS IN 2016

TABLE A-1: SUMMARY STATISTICS FOR DISSOLVED OXYGEN MEASURED
DURING CROSS-SECTIONAL SURVEYS IN 2016

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									
05/13/2016	2.7	7.9	2.8	7	6.84	7.29	7.08	0.18	2.50
08/05/2016	2.6	6.4	1.4	7	5.27	7.23	6.28	0.86	13.69
10/06/2016	1.9	6.7	1.4	7	6.34	7.22	6.64	0.31	4.73
Foster Avenue									
05/13/2016	3.6	9.9	3.4	8	8.35	8.43	8.38	0.03	0.31
08/05/2016	1.2	9.0	1.6	8	7.28	7.59	7.50	0.13	1.72
10/06/2016	4.4	9.5	1.8	9	7.87	8.07	7.91	0.06	0.80
-----North Branch Chicago River-----									
Central Park Avenue									
08/18/2016	1.1	2.1	1.0	6	5.10	5.21	5.17	0.05	0.90
10/06/2016	0.9	1.2	0.5	4	7.11	7.42	7.19	0.15	2.11
Addison Street									
06/02/2016	5.6	8.7	8.9	11	6.40	6.60	6.50	0.07	1.03
08/26/2016	8.9	9.0	3.4	12	6.22	6.80	6.52	0.15	2.34
10/26/2016	7.9	7.6	2.3	8	8.10	8.16	8.14	0.02	0.25

TABLE A-1 (CONTINUED): SUMMARY STATISTICS FOR DISSOLVED OXYGEN MEASURED DURING CROSS-SECTIONAL SURVEYS IN 2016

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									
06/02/2016	11.7	17.4	17.1	12	3.57	5.91	5.49	0.62	11.35
08/26/2016	15.5	15.1	13.0	12	5.11	5.64	5.46	0.15	2.73
10/26/2016	12.6	15.8	7.9	11	5.86	6.44	6.27	0.16	2.53
-----Chicago River-----									
Clark Street									
06/02/2016	19.2	24.3	14.5	12	8.53	9.84	9.02	0.44	4.85
08/26/2016	20.4	22.8	19.4	12	9.83	10.73	10.19	0.28	2.72
10/26/2016	11.8	22.4	17.6	12	6.93	7.96	7.76	0.28	3.61
-----South Branch Chicago River-----									
Loomis Street									
05/19/2016	20.8	22.1	15.0	12	5.55	5.94	5.75	0.10	1.78
08/09/2016	18.6	22.3	20.6	12	4.65	5.05	4.71	0.14	2.89
10/11/2016	17.9	21.5	18.8	12	5.04	5.25	5.13	0.05	1.03

AI-2

TABLE A-1 (CONTINUED): SUMMARY STATISTICS FOR DISSOLVED OXYGEN MEASURED DURING CROSS-SECTIONAL SURVEYS IN 2016

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						
-----Bubbly Creek-----									
36th Street									
05/19/2016	4.2	4.4	5.3	9	0.00	0.40	0.13	0.13	104.01
08/09/2016	4.5	4.6	5.0	9	3.19	9.30	5.69	2.24	39.41
10/11/2016	4.3	5.4	4.9	9	3.54	6.63	5.38	1.21	22.48
Interstate Highway 55									
05/19/2016	5.1	10.5	7.6	11	0.00	1.24	0.12	0.37	302.41
08/09/2016	5.1	12.0	10.3	11	0.11	3.66	2.32	0.89	38.54
10/11/2016	4.2	11.5	9.6	11	2.62	3.24	2.98	0.22	7.47
-----Chicago Sanitary and Ship Canal-----									
Cicero Avenue									
05/19/2016	14.4	19.5	6.4	11	2.11	3.10	2.79	0.30	10.94
08/09/2016	14.5	18.8	7.4	11	2.51	2.94	2.62	0.12	4.59
10/11/2016	12.8	19.6	9.1	12	3.77	4.10	3.86	0.09	2.32
B&O Railroad									
05/19/2016	15.1	21.5	7.3	11	5.17	5.88	5.48	0.21	3.82
08/09/2016	15.1	20.5	7.0	11	4.84	5.44	5.06	0.18	3.50
10/11/2016	13.1	21.5	7.0	11	5.16	5.37	5.22	0.06	1.10

AI-3

TABLE A-1 (CONTINUED): SUMMARY STATISTICS FOR DISSOLVED OXYGEN MEASURED DURING CROSS-SECTIONAL SURVEYS IN 2016

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 (Continued)-----									
Lockport Powerhouse									
05/27/2016	25.1	29.4	13.3	12	0.70	0.89	0.78	0.07	8.94
08/11/2016	30.5	29.3	23.5	12	3.50	3.99	3.66	0.13	3.65
10/07/2016	25.3	27.3	29.5	12	5.37	5.55	5.45	0.06	1.14
-----Little Calumet River-----									
C&W Indiana Railroad									
06/01/2016	7.8	14.3	8.5	11	6.60	7.62	7.28	0.34	4.74
08/17/2016	8.2	14.7	8.3	12	6.41	8.38	7.43	0.68	9.09
10/19/2016	7.2	15.5	9.5	11	8.54	9.11	8.80	0.24	2.76
Halsted Street									
05/25/2016	3.0	14.1	7.4	9	7.68	9.02	8.09	0.50	6.16
08/17/2016	2.5	14.4	11.7	10	6.33	7.30	6.81	0.40	5.83
10/19/2016	8.0	14.9	5.5	11	6.75	7.08	6.90	0.07	1.08
Ashland Avenue									
06/03/2016	2.2	5.4	1.5	6	4.14	4.36	4.20	0.08	1.96
08/14/2016	1.3	4.1	0.5	6	5.84	6.12	6.04	0.10	3.50
10/07/2016	2.0	5.0	2.5	5	6.19	6.26	6.22	0.03	0.53

TABLE A-1 (CONTINUED): SUMMARY STATISTICS FOR DISSOLVED OXYGEN MEASURED DURING CROSS-SECTIONAL SURVEYS IN 2016

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									
05/25/2016	8.4	13.7	8.3	12	6.47	6.99	6.71	0.16	2.33
08/17/2016	5.0	13.5	9.1	11	5.06	5.78	5.28	0.19	3.57
10/19/2016	9.5	14.0	9.5	12	5.63	6.25	5.83	0.18	3.09
Route 83									
05/25/2016	12.5	15.0	8.8	12	6.14	6.65	6.25	0.13	2.11
08/17/2016	13.0	13.9	10.0	12	4.98	5.18	5.07	0.08	1.50
10/19/2016	14.3	12.9	9.5	12	5.82	6.76	6.11	0.26	4.30
-----Des Plaines River-----									
Devon Avenue									
06/20/2016	0.7	1.6	1.0	4	6.69	6.76	6.73	0.03	0.43
08/10/2016	1.0	2.0	1.0	6	5.58	5.77	5.71	0.09	1.51
10/03/2016	2.0	1.3	1.3	6	6.71	7.13	6.79	0.17	2.48
Ogden Avenue									
06/20/2016	0.8	0.8	0.9	3	7.31	7.78	7.59	0.25	3.24
08/10/2016	0.9	0.2	1.2	4	5.92	6.41	5.92	0.35	5.95
10/03/2016	2.3	2.7	2.4	6	7.17	7.26	7.17	0.05	0.69

S-IV

TABLE A-1 (CONTINUED): SUMMARY STATISTICS FOR DISSOLVED OXYGEN MEASURED DURING CROSS-SECTIONAL SURVEYS IN 2016

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						
-----Salt Creek-----									
Busse Lake Dam									
06/20/2016	1.3	2.8	1.0	5	8.01	8.18	8.11	0.07	0.87
08/10/2016	1.3	3.3	1.8	6	8.21	8.49	8.29	0.10	1.21
10/03/2016	2.7	3.0	2.1	6	8.70	8.90	8.79	0.07	0.75
J. F. Kennedy Boulevard									
06/20/2016	1.3	2.8	1.0	5	7.02	7.75	7.40	0.34	4.62
08/10/2016	1.3	3.3	1.8	6	7.00	7.35	7.22	0.14	1.95
10/03/2016	2.7	3.0	2.1	5	8.40	8.48	8.45	0.03	0.37
Wolf Road									
06/20/2016	0.6	1.7	1.1	3	7.68	7.89	7.77	0.11	1.38
08/10/2016	1.1	2.0	1.4	5	6.83	6.88	6.84	0.02	0.32
10/03/2016	0.8	1.8	1.4	6	7.95	8.08	8.03	0.06	0.73

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.