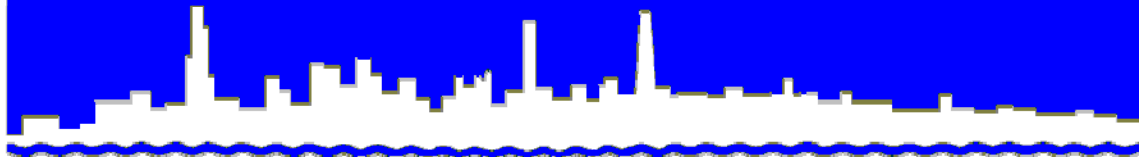


Protecting Our Water Environment



Metropolitan Water Reclamation District of Greater Chicago

*MONITORING AND RESEARCH
DEPARTMENT*

REPORT NO. 16-33

***CONTINUOUS DISSOLVED OXYGEN MONITORING
IN THE CHICAGO AREA WATERWAYS
DURING 2015***

October 2016

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TABLE OF CONTENTS

	<u>Page</u>
LIST OF TABLES	ii
LIST OF FIGURES	iii
LIST OF ACRONYMS	v
ACKNOWLEDGMENT	vi
DISCLAIMER	vi
INTRODUCTION	1
MONITORING LOCATIONS AND APPLICABLE DISSOLVED OXYGEN STANDARDS	2
Locations and Descriptions	2
Designated Uses for 2015	2
Dissolved Oxygen Water Quality Standards for 2015	8
MATERIALS AND METHODS	9
Water Quality Monitors	9
Data Management and Review	9
Cross-Sectional Surveys	10
RESULTS	11
REFERENCES	34
APPENDIX A	
Summary Statistics for Dissolved Oxygen Measured During Cross-Sectional Surveys in 2015	A-1

LIST OF TABLES

<u>Table No.</u>		<u>Page</u>
1	Continuous Dissolved Oxygen Monitoring Stations During 2015	4
2	Minimum, Maximum, and Mean Hourly Dissolved Oxygen Concentrations During 2015	12
3	Number and Percent of Dissolved Oxygen Values Not Meeting Acceptance Criteria During 2015	13
4	Percent of Dissolved Oxygen Values in Selected Ranges During 2015	14
A-1	Summary Statistics for Dissolved Oxygen Measured During Cross-Sectional Surveys in 2015	A-1

LIST OF FIGURES

<u>Figure No.</u>		<u>Page</u>
1	2015 Continuous Dissolved Oxygen Monitoring Stations	3
2	Dissolved Oxygen Concentration Measured Hourly at Foster Avenue on the North Shore Channel From January 1, 2015 Through December 31, 2015	15
3	Dissolved Oxygen Concentration Measured Hourly at Addison Street on the North Branch Chicago River From January 1, 2015 Through December 31, 2015	16
4	Dissolved Oxygen Concentration Measured Hourly at Division Street on the North Branch Chicago River From January 1, 2015 Through December 31, 2015	17
5	Dissolved Oxygen Concentration Measured Hourly at Clark Street on the Chicago River From January 1, 2015 Through December 31, 2015	18
6	Dissolved Oxygen Concentration Measured Hourly at Loomis Street on the South Branch Chicago River From January 1, 2015 Through December 31, 2015	19
7	Dissolved Oxygen Concentration Measured Hourly at 36th Street on Bubbly Creek From January 1, 2015 Through December 31, 2015	20
8	Dissolved Oxygen Concentration Measured Hourly at Interstate Highway 55 on Bubbly Creek From January 1, 2015 Through December 31, 2015	21
9	Dissolved Oxygen Concentration Measured Hourly at Cicero Avenue on the Chicago Sanitary and Ship Canal From January 1, 2015 Through December 31, 2015	22
10	Dissolved Oxygen Concentration Measured Hourly at B&O Central Railroad on the Chicago Sanitary and Ship Canal From January 1, 2015 Through December 31, 2015	23
11	Dissolved Oxygen Concentration Measured Hourly at Lockport Powerhouse on the Chicago Sanitary and Ship Canal From January 1, 2015 Through December 31, 2015	24
12	Dissolved Oxygen Concentration Measured Hourly at C&W Indiana Railroad on the Little Calumet River From January 1, 2015 Through December 31, 2015	25

LIST OF FIGURES (CONTINUED)

<u>Figure No.</u>		<u>Page</u>
13	Dissolved Oxygen Concentration Measured Hourly at Halsted Street on the Little Calumet River From January 1, 2015 Through December 31, 2015	26
14	Dissolved Oxygen Concentration Measured Hourly at Ashland Avenue on the Little Calumet River From January 1, 2015 Through December 31, 2015	27
15	Dissolved Oxygen Concentration Measured Hourly at Cicero Avenue on the Calumet-Sag Channel From March 4, 2015 Through December 31, 2015	28
16	Dissolved Oxygen Concentration Measured Hourly at Route 83 on the Calumet-Sag Channel From January 1, 2015 Through December 31, 2015	29
17	Dissolved Oxygen Concentration Measured Hourly at Devon Avenue on the Des Plaines River From January 1, 2015 Through December 31, 2015	30
18	Dissolved Oxygen Concentration Measured Hourly at Busse Lake Dam on Salt Creek From January 1, 2015 Through December 31, 2015	31
19	Dissolved Oxygen Concentration Measured Hourly at J.F. Kennedy Boulevard on Salt Creek From January 1, 2015 Through December 31, 2015	32
20	Dissolved Oxygen Concentration Measured Hourly at Wolf Road on Salt Creek From January 1, 2015 Through December 31, 2015	33

LIST OF ACRONYMS

Abbreviation\Acronym	Definition
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
Monitor	Continuous Water Quality Monitor
O'Brien	Terrence J. O'Brien
RR	Railroad
SEPA	Sidestream Elevated Pool Aeration Station
WRP	Water Reclamation Plant
YSI	YSI Incorporated

ACKNOWLEDGMENT

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Particular thanks are due to Ms. Jenna Coyle for reviewing, editing, and preparing the report for print.

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 possible. 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 (MWRDGC, 2008). The CAWS has two river systems: the Calumet River System and the Chicago River System (CRS). The Upper Des Plaines River System also flows through portions of the Chicago area and its suburbs. It is composed of natural streams that are highly influenced by urbanization which receive stormwater runoff and treated municipal wastewater. Salt Creek is a tributary to the Upper Des Plaines River System and flows through part of the District's service area.

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. The duration of the monitoring program was extended and the scope was expanded to include the Calumet River System in 2001, and later, the Chicago Metropolitan area wadeable streams in 2005. 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). 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, 2015, through December 31, 2015, for the deep-draft waterways and wadeable streams within the District's service area, including the CAWS and the Upper Des Plaines River system.

MONITORING LOCATIONS AND APPLICABLE DISSOLVED OXYGEN STANDARDS

Locations and Descriptions

The Continuous Dissolved Oxygen Monitoring (CDOM) Program supplies the District with water quality data throughout the year for both the wadeable and deep-draft waterways within its jurisdiction. The 19 CDOM stations monitored in 2015 are shown in Figure 1 and described in Table 1.

There were 14 monitoring stations in the CAWS. The deep-draft monitoring stations included one location 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 five stations in the Chicago Metropolitan Area wadeable streams. Four wadeable monitoring stations were located in the Upper Des Plaines River System: one on the Upper Des Plaines River and three on Salt Creek. One wadeable monitoring station was in the Calumet River System on the Little Calumet River.

The CDOM station at the Busse Lake Dam was not in service from August 18, 2015, through December 9, 2015, due to construction on the dam gates for Busse Lake. The CDOM station at Lockport was out of service from August 24, 2015, through September 15, 2015, due to a United States Army Corps of Engineer project to reconstruct the channel wall. The Lockport CDOM station was relocated approximately 30 meters east to accommodate this effort.

Designated Uses for 2015

The IPCB has assigned use designations for each water body 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 Chicago Area Waterway System Aquatic Life Use A (CAWS A) Waters. The Chicago Sanitary and Ship Canal is designated as Chicago Area Waterway System and Brandon Pool Aquatic Life Use B (CAWS B) Waters.

FIGURE 1: 2015 CONTINUOUS DISSOLVED OXYGEN MONITORING STATIONS

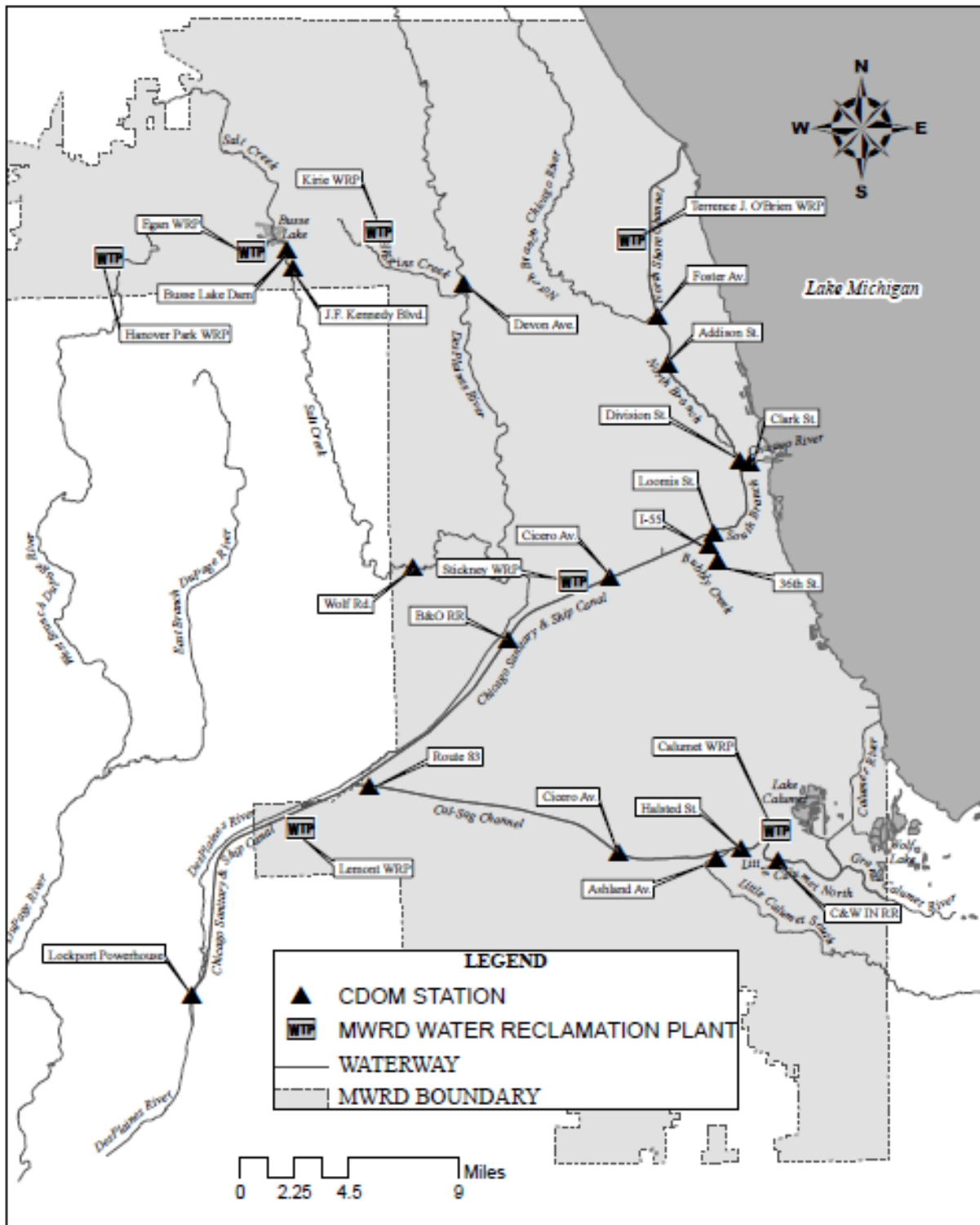


TABLE 1: CONTINUOUS DISSOLVED OXYGEN
MONITORING STATIONS DURING 2015

Monitoring Station	Waterway	Description of Monitoring Station
<u>Chicago River System</u>		
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.
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.
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.

TABLE 1 (Continued): CONTINUOUS DISSOLVED OXYGEN
MONITORING STATIONS DURING 2015

Monitoring Station	Waterway	Description of Monitoring Station
<u>Chicago River System (Continued)</u>		
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.
<u>Calumet River System</u>		
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.

TABLE 1 (Continued): CONTINUOUS DISSOLVED OXYGEN
MONITORING STATIONS DURING 2015

Monitoring Station	Waterway	Description of Monitoring Station
<u>Calumet River System (Continued)</u>		
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.
<u>Upper Des Plaines River System</u>		
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 2015

Monitoring Station	Waterway	Description of Monitoring Station
<u>Upper Des Plaines River System (Continued)</u>		
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

Dissolved Oxygen Water Quality Standards for 2015

The IPCB has established water quality standards for DO, which were updated for CAWS A and B Waters effective July 1, 2015. In Bubbly Creek, the DO shall not be less than 4.0 mg/L at any time. For CAWS 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 7 days from August through February; and the DO shall not be below 5.0 mg/L at any time from March through July. For CAWS 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 7 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.

MATERIALS AND METHODS

Water Quality Monitors

The continuous water quality monitors (monitors) used to collect these data were 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 and safeguard the monitors from marine navigation and vandalism, the monitors were deployed into stainless steel housings. A fixed length of 8-inch diameter stainless steel 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 water sample was collected next to the protective housing for DO analysis using the Winkler method for subsequent comparison 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 calibration 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 exported electronically directly 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.

The review process 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.

A comprehensive description of methods is presented in Revision 2.0 of the Continuous Dissolved Oxygen Monitoring Program Quality Assurance Project Plan, Effective April 1, 2011.

Cross-Sectional Surveys

During the spring, summer, and fall of 2015, cross-sectional DO surveys were conducted in the Chicago River System, 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 19 stations during 2015 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 2015 are summarized in Table 3.

The percent distribution of DO concentrations in 1 mg/L increments from <1.0 mg/L to >10.0 mg/L at the 19 monitoring stations during 2015 are presented in Table 4.

Individual graphs showing hourly DO concentrations at each monitoring station are presented in Figures 2 through 20.

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 2015

Monitoring Station	Waterway	DO Concentration (mg/L)		
		Minimum	Maximum	Mean
<u>Chicago River System</u>				
Foster Avenue	North Shore Channel	2.6	12.5	7.4
Addison Street	North Branch Chicago River	0.5	12.3	7.3
Division Street	North Branch Chicago River	0.2	12.3	7.1
Clark Street	Chicago River	2.0	13.1	9.0
Loomis Street	South Branch Chicago River	1.2	12.1	7.3
36 th Street	Bubbly Creek	0.0	29.8	6.3
Interstate Highway 55	Bubbly Creek	0.0	24.3	5.1
Cicero Avenue	Chicago Sanitary and Ship Canal	0.0	11.6	6.4
B&O Central Railroad	Chicago Sanitary and Ship Canal	0.6	9.8	6.5
Lockport Powerhouse	Chicago Sanitary and Ship Canal	0.1	10.0	5.7
<u>Calumet River System</u>				
C&W Indiana Railroad	Little Calumet River	1.1	19.8	9.2
Halsted Street	Little Calumet River	0.4	22.2	6.9
Ashland Avenue	Little Calumet River	1.5	23.2	8.8
Cicero Avenue	Calumet-Sag Channel	0.2	12.9	7.1
Route 83	Calumet-Sag Channel	0.7	14.0	6.8
<u>Des Plaines River System</u>				
Devon Avenue	Des Plaines River	2.0	17.5	9.2
Busse Lake Dam	Salt Creek	0.0	14.0	9.3
J.F. Kennedy Boulevard	Salt Creek	4.3	14.3	8.6
Wolf Road	Salt Creek	2.5	19.9	9.6

TABLE 3: NUMBER AND PERCENT OF DISSOLVED OXYGEN VALUES NOT MEETING ACCEPTANCE CRITERIA DURING 2015

Monitoring Station	Waterway	Number of DO Values Rejected	Percent of DO Values Rejected
<u>Chicago River System</u>			
Foster Avenue	North Shore Channel	0	0
Addison Street	North Branch Chicago River	456	5 ^a
Division Street	North Branch Chicago River	2,021	23 ^b
Clark Street	Chicago River	1,008	12 ^c
Loomis Street	South Branch Chicago River	505	6 ^d
36 th Street	Bubbly Creek	0	0
Interstate Highway 55	Bubbly Creek	231	3 ^e
Cicero Avenue	Chicago Sanitary and Ship Canal	0	0
B&O Central Railroad	Chicago Sanitary and Ship Canal	134	2 ^f
Lockport Powerhouse	Chicago Sanitary and Ship Canal	739	8 ^g
<u>Calumet River System</u>			
C&W Indiana Railroad	Little Calumet River	2,532	29 ^h
Halsted Street	Little Calumet River	2,885	33 ⁱ
Ashland Avenue	Little Calumet River	1,005	12 ^j
Cicero Avenue	Calumet-Sag Channel	869	10 ^k
Route 83	Calumet-Sag Channel	554	6 ^l
<u>Des Plaines River System</u>			
Devon Avenue	Des Plaines River	394	5 ^m
Busse Lake Dam	Salt Creek	0	0
J.F. Kennedy Boulevard	Salt Creek	0	0
Wolf Road	Salt Creek	1,512	17 ⁿ

^a7/23 – 8/11/15 equipment failure.

^b3/17 – 4/9/15, 9/24 – 10/15/15 monitor failed criteria 2 and 3. 10/15 – 11/4/15, 11/25 – 12/15/15 equipment failure.

^c3/17 – 4/9/15 equipment failure. 4/9 – 4/28/15 monitor failed criterion 1.

^d6/18 – 7/9/15 monitor failed criterion 1.

^e12/22 – 12/31/15 monitor failed criteria 2 and 3.

^f1/1 – 1/6/15 monitor failed criteria 1 and 3.

^g11/5 – 12/2/15 equipment failure.

^h1/1 – 3/13/15 monitor failed criteria 2 and 3. 3/13 – 3/31/15, 3/31 – 4/16/15 equipment failure.

ⁱ2/4 – 3/31/15, 6/25 – 7/17/15, 8/5 – 8/26/15 monitor failed criteria 2 and 3. 6/2 – 6/25/15 equipment failure.

^j6/3 – 6/24/15 monitor failed criteria 2 and 3. 11/18 – 12/9/15 monitor failed criterion 1.

^k6/2 – 6/25/15 monitor failed criteria 2 and 3. 6/25 – 7/8/15 equipment failure.

^l11/19 – 12/10/15 monitor failed criteria 2 and 3.

^m3/11 – 3/25/15 equipment failure.

ⁿ5/29 – 6/17/15, 10/21 – 11/12/15 monitor failed criteria 2 and 3. 11/12 – 12/2/15 equipment failure.

TABLE 4: PERCENT OF DISSOLVED OXYGEN VALUES IN SELECTED RANGES DURING 2015

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
<u>Chicago River System</u>												
Foster Avenue	North Shore Channel	0	0	<1	<1	<1	4	29	40	23	2	<1
Addison Street	North Branch Chicago River	<1	0	<1	<1	<1	11	28	32	18	8	2
Division Street	North Branch Chicago River	<1	<1	<1	1	4	15	33	16	17	11	3
Clark Street	Chicago river	0	<1	<1	<1	<1	<1	2	21	31	21	24
Loomis Street	South Branch Chicago River	0	<1	<1	<1	3	15	29	21	18	7	6
36 th Street	Bubbly Creek	32	3	5	4	4	6	5	5	5	6	25
Interstate Highway 55	Bubbly Creek	21	9	6	6	8	10	9	6	6	8	10
Cicero Avenue	Chicago Sanitary and Ship Canal	1	1	3	7	16	18	16	13	11	11	4
B&O Central Railroad	Chicago Sanitary and Ship Canal	<1	<1	<1	2	12	25	21	18	15	5	0
Lockport Powerhouse	Chicago Sanitary and Ship Canal	<1	2	5	16	15	19	12	18	9	4	<1
<u>Calumet River System</u>												
C&W Indiana Railroad	Little Calumet River	0	<1	<1	1	4	6	9	13	17	13	36
Halsted Street	Little Calumet River	4	2	3	2	3	8	21	27	19	7	4
Ashland Avenue	Little Calumet River	0	<1	<1	2	8	18	17	9	7	5	34
Cicero Avenue	Calumet-Sag Channel	<1	3	1	1	5	16	22	16	17	14	5
Route 83	Calumet-Sag Channel	<1	<1	2	7	14	14	17	11	14	13	7
<u>Des Plaines River System</u>												
Devon Avenue	Des Plaines River	0	0	<1	<1	1	12	17	10	11	7	41
Busse Lake Dam	Salt Creek	2	2	3	3	4	5	6	13	5	4	54
J.F. Kennedy Boulevard	Salt Creek	0	0	0	0	1	5	13	18	20	19	24
Wolf Road	Salt Creek	0	0	<1	<1	<1	5	14	18	11	10	43

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

FIGURE 2: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT FOSTER AVENUE ON THE NORTH SHORE CHANNEL FROM JANUARY 1, 2015 THROUGH DECEMBER 31, 2015

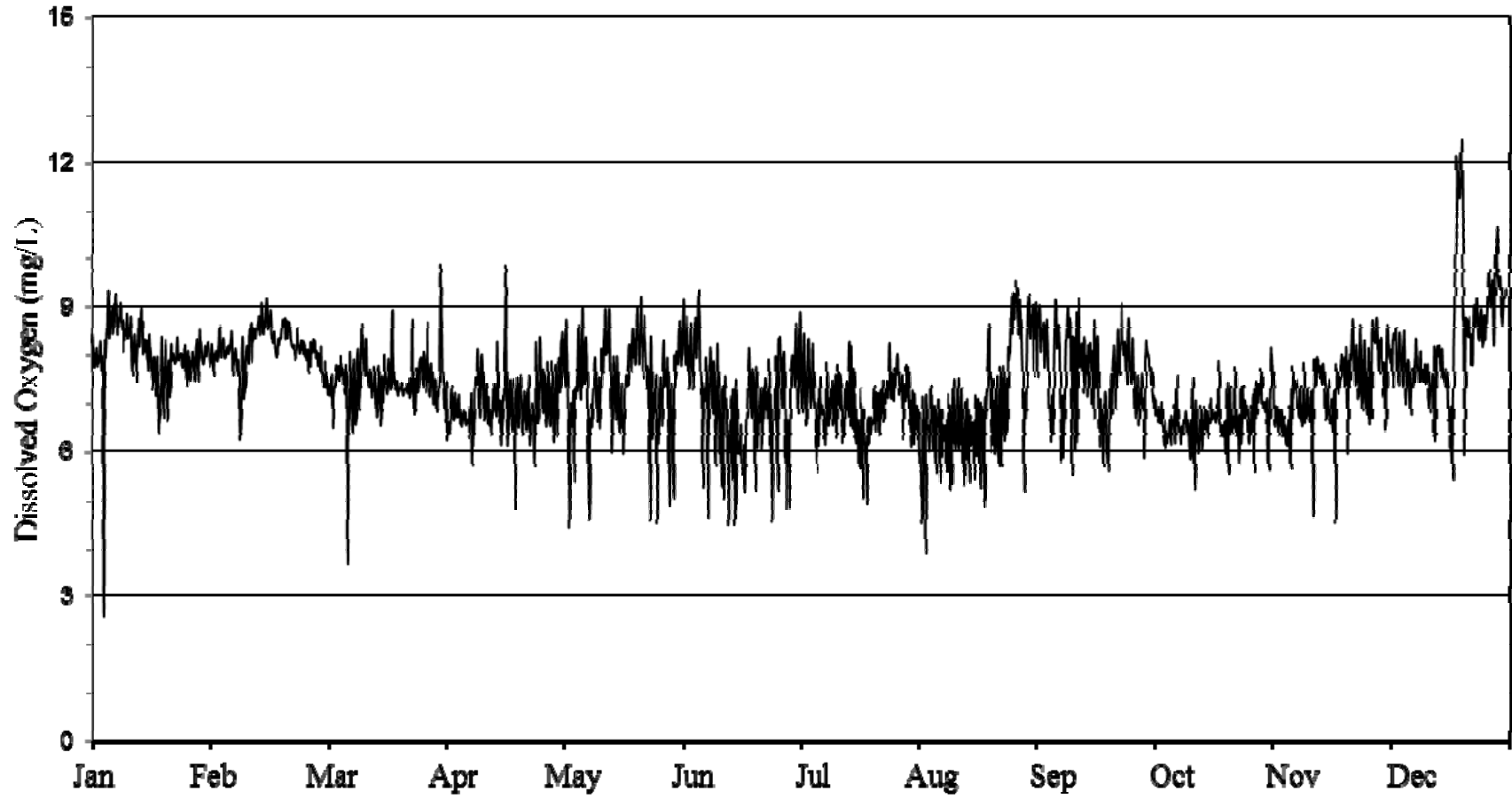


FIGURE 3: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT ADDISON STREET ON THE NORTH BRANCH CHICAGO RIVER FROM JANUARY 1, 2015 THROUGH DECEMBER 31, 2015

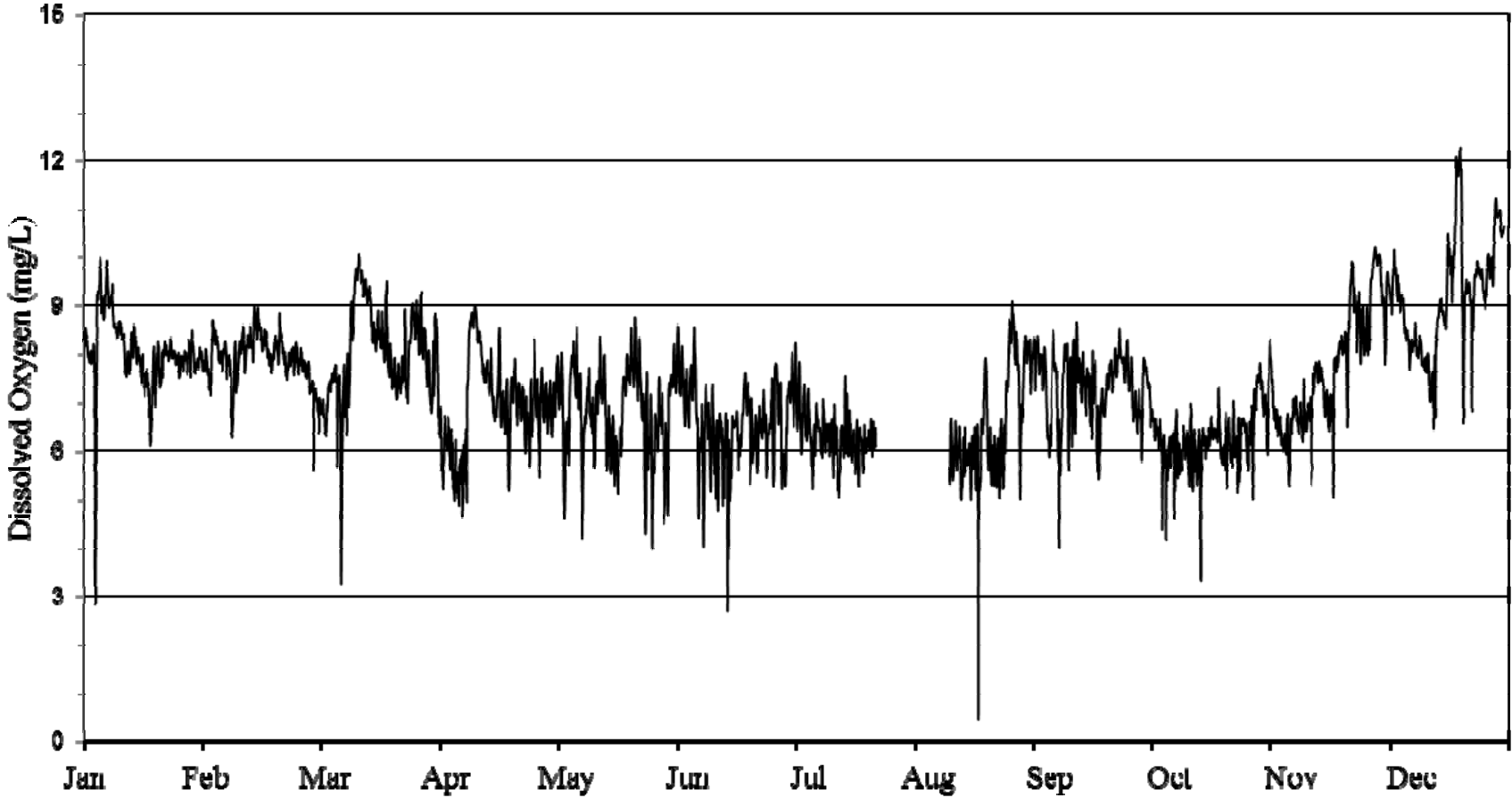


FIGURE 4: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT DIVISION STREET ON THE NORTH BRANCH CHICAGO RIVER FROM JANUARY 1, 2015 THROUGH DECEMBER 31, 2015

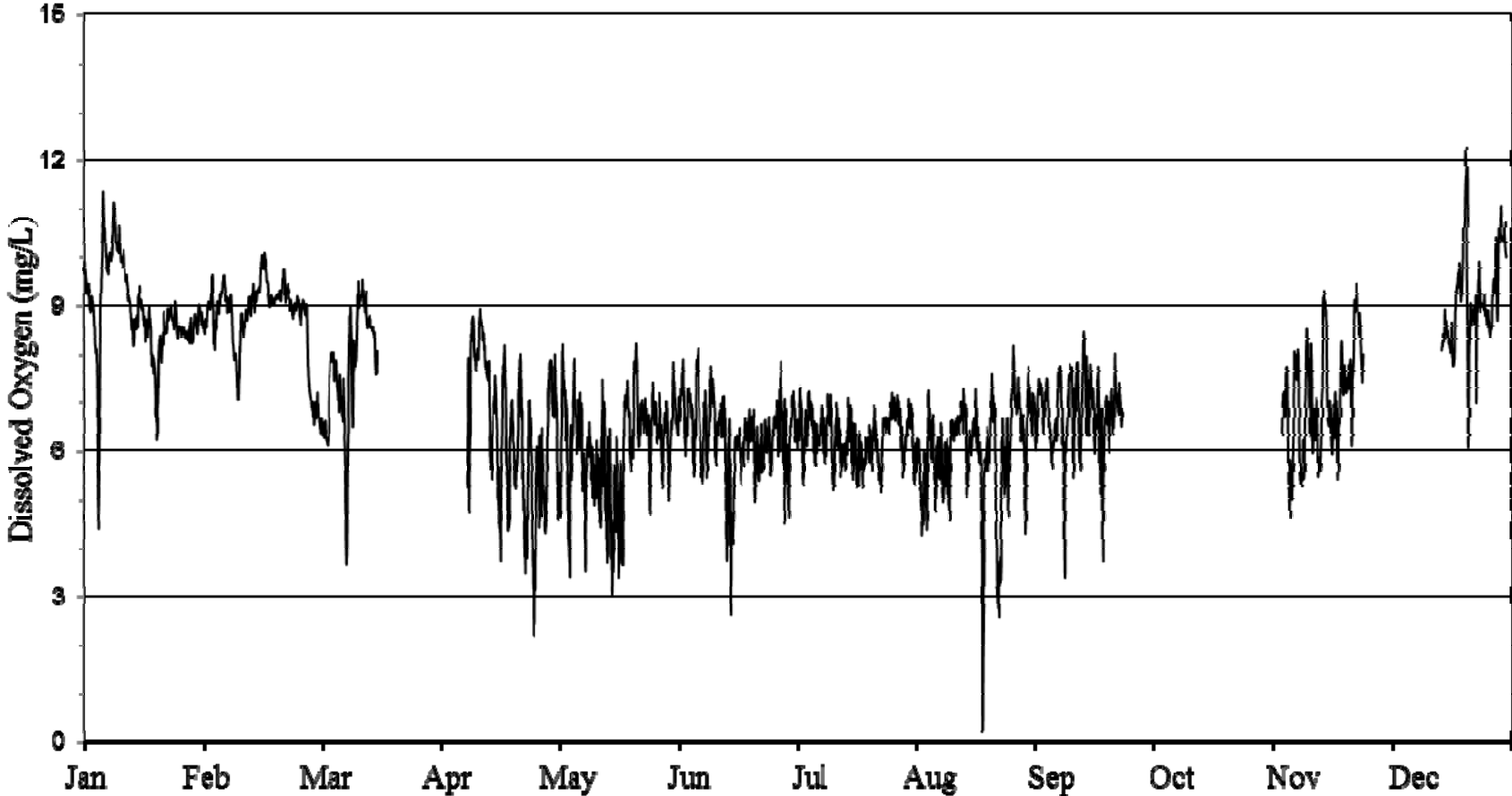


FIGURE 5: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT CLARK STREET ON THE CHICAGO RIVER FROM JANUARY 1, 2015 THROUGH DECEMBER 31, 2015

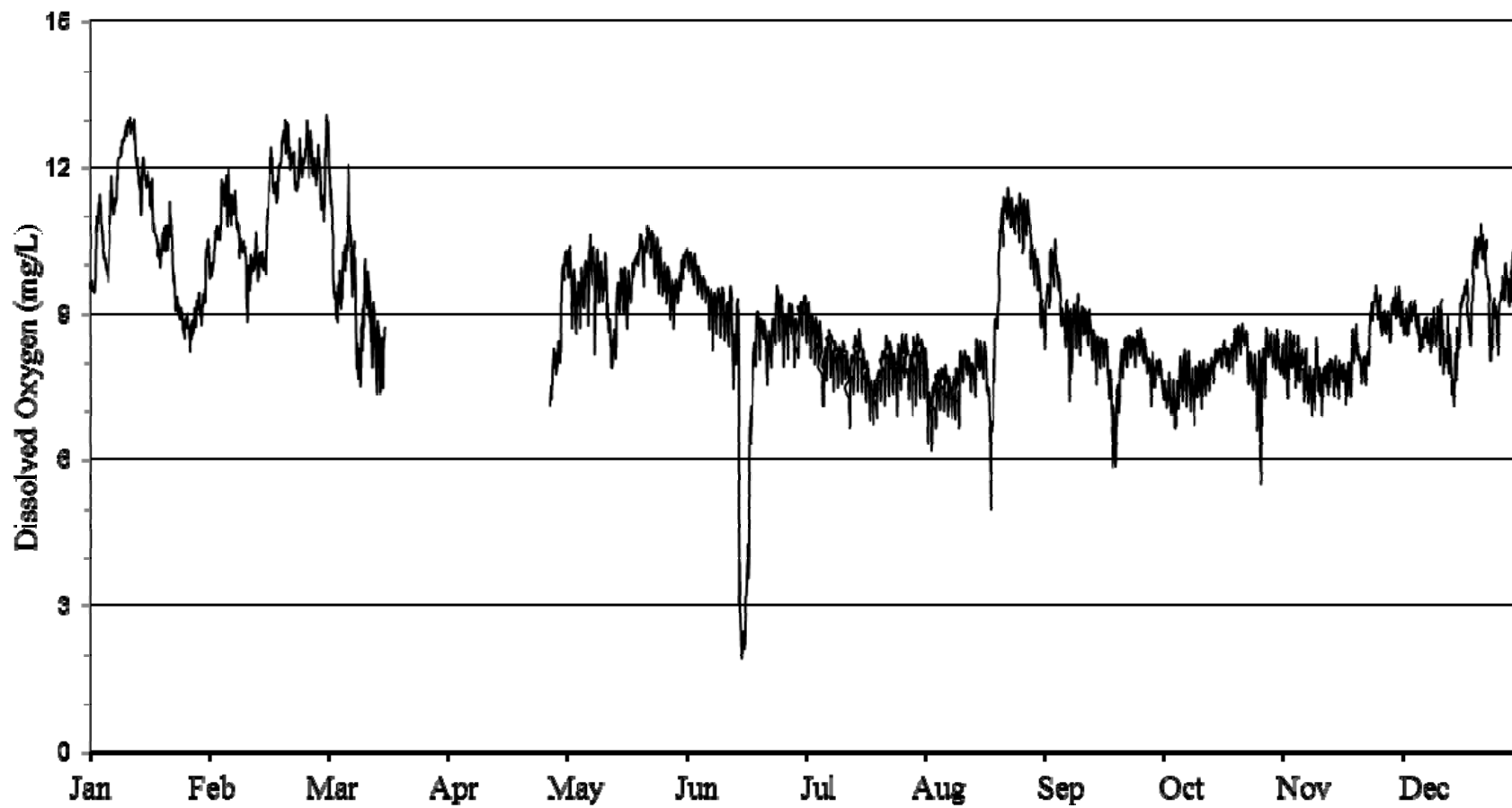


FIGURE 6: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT LOOMIS STREET ON THE SOUTH BRANCH CHICAGO RIVER FROM JANUARY 1, 2015 THROUGH DECEMBER 31, 2015

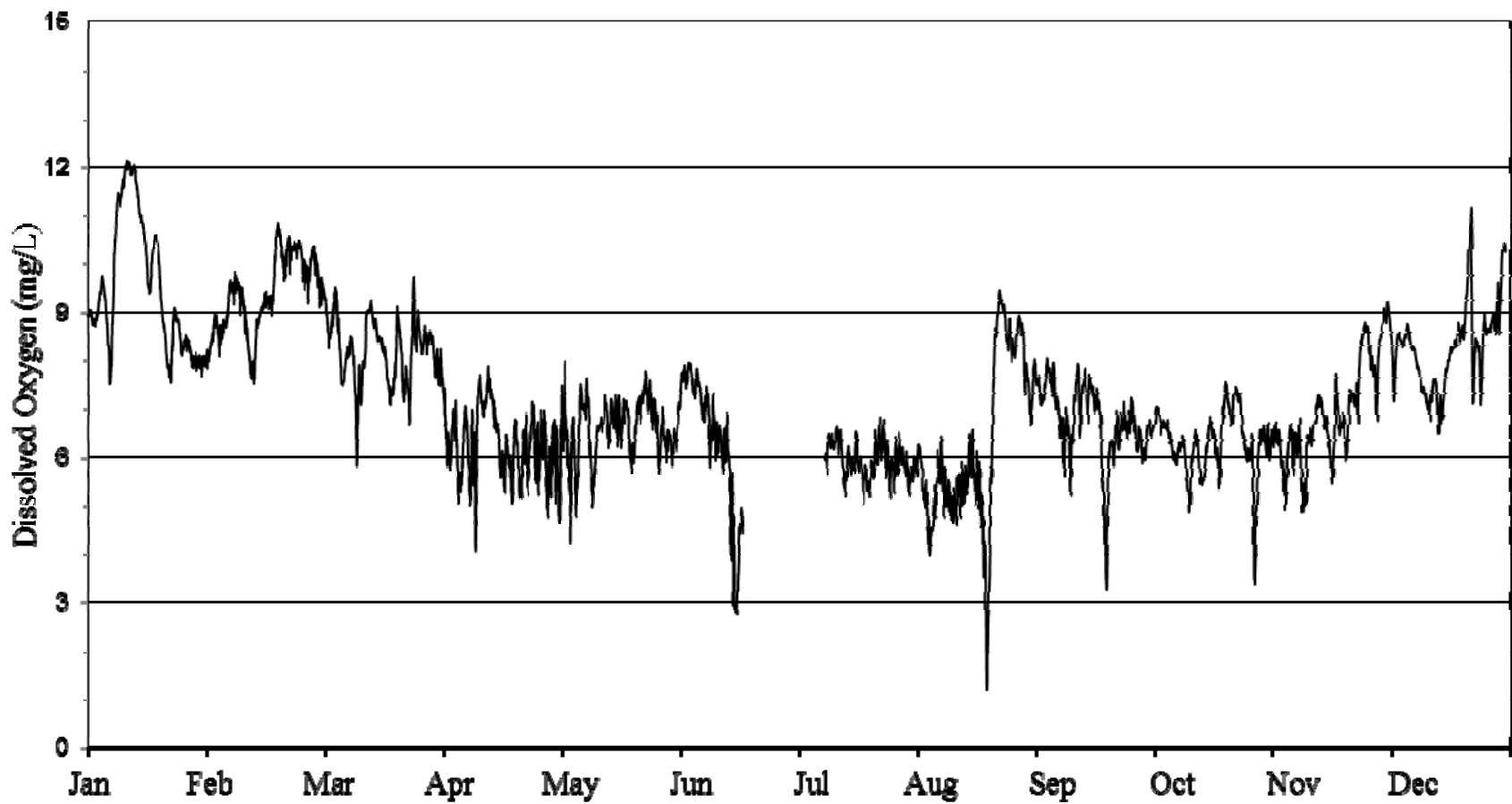


FIGURE 7: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT 36th STREET ON BUBBLY CREEK FROM JANUARY 1, 2015 THROUGH DECEMBER 31, 2015

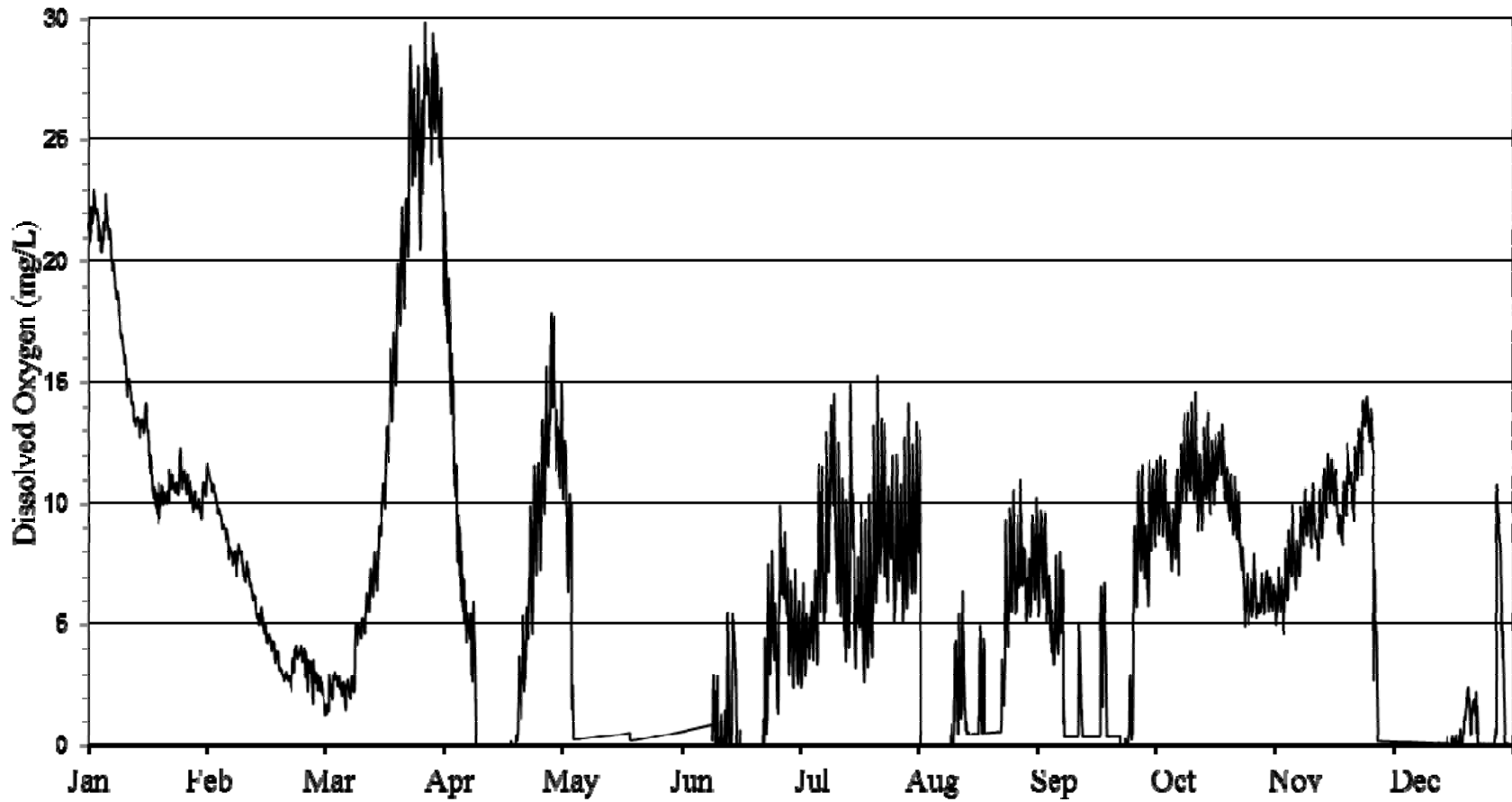


FIGURE 8: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT INTERSTATE HIGHWAY 55 ON BUBBLY CREEK FROM JANUARY 1, 2015 THROUGH DECEMBER 31, 2015

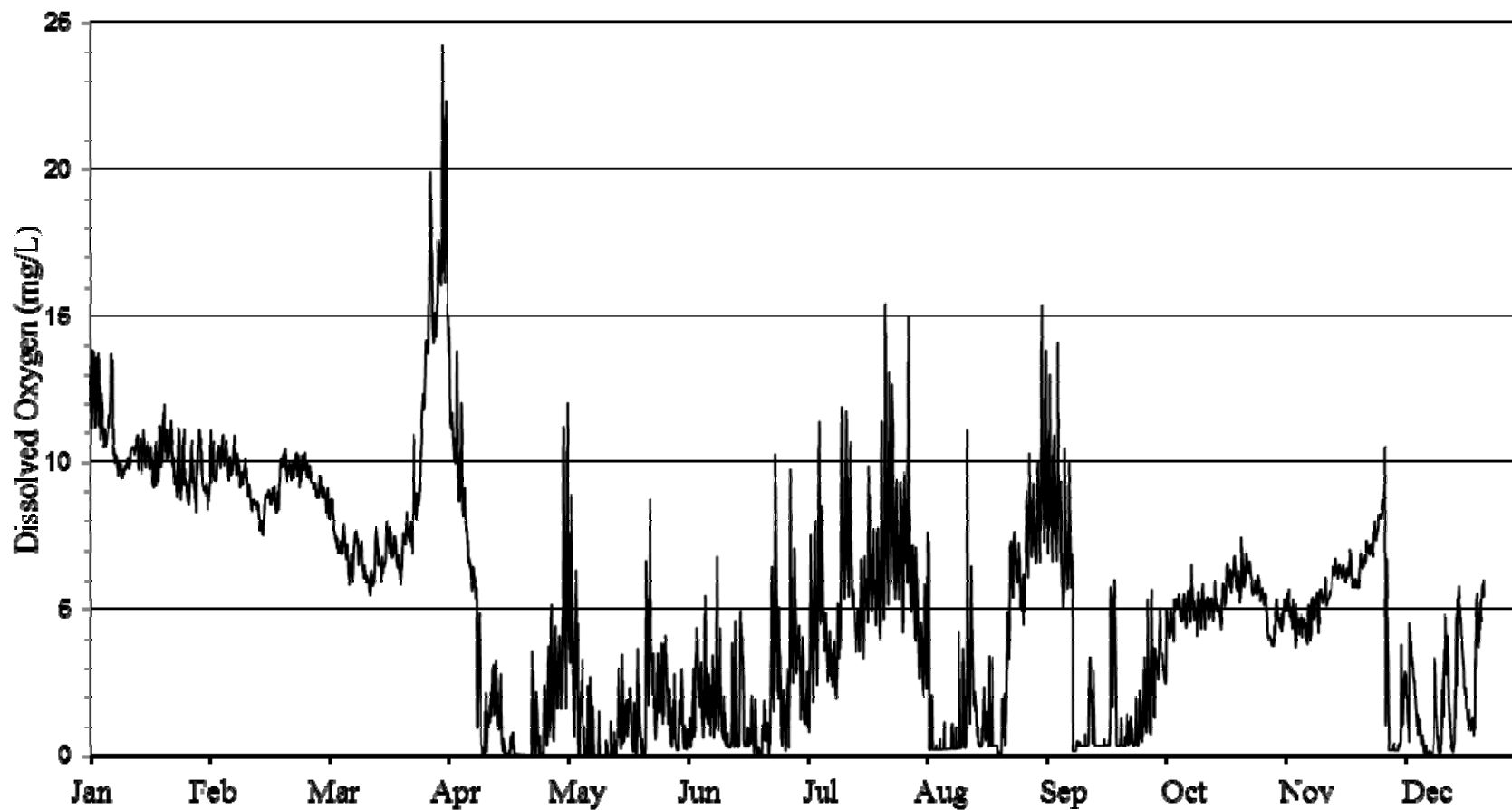


FIGURE 9: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT CICERO AVENUE ON THE CHICAGO SANITARY AND SHIP CANAL FROM JANUARY 1, 2015 THROUGH DECEMBER 31, 2015

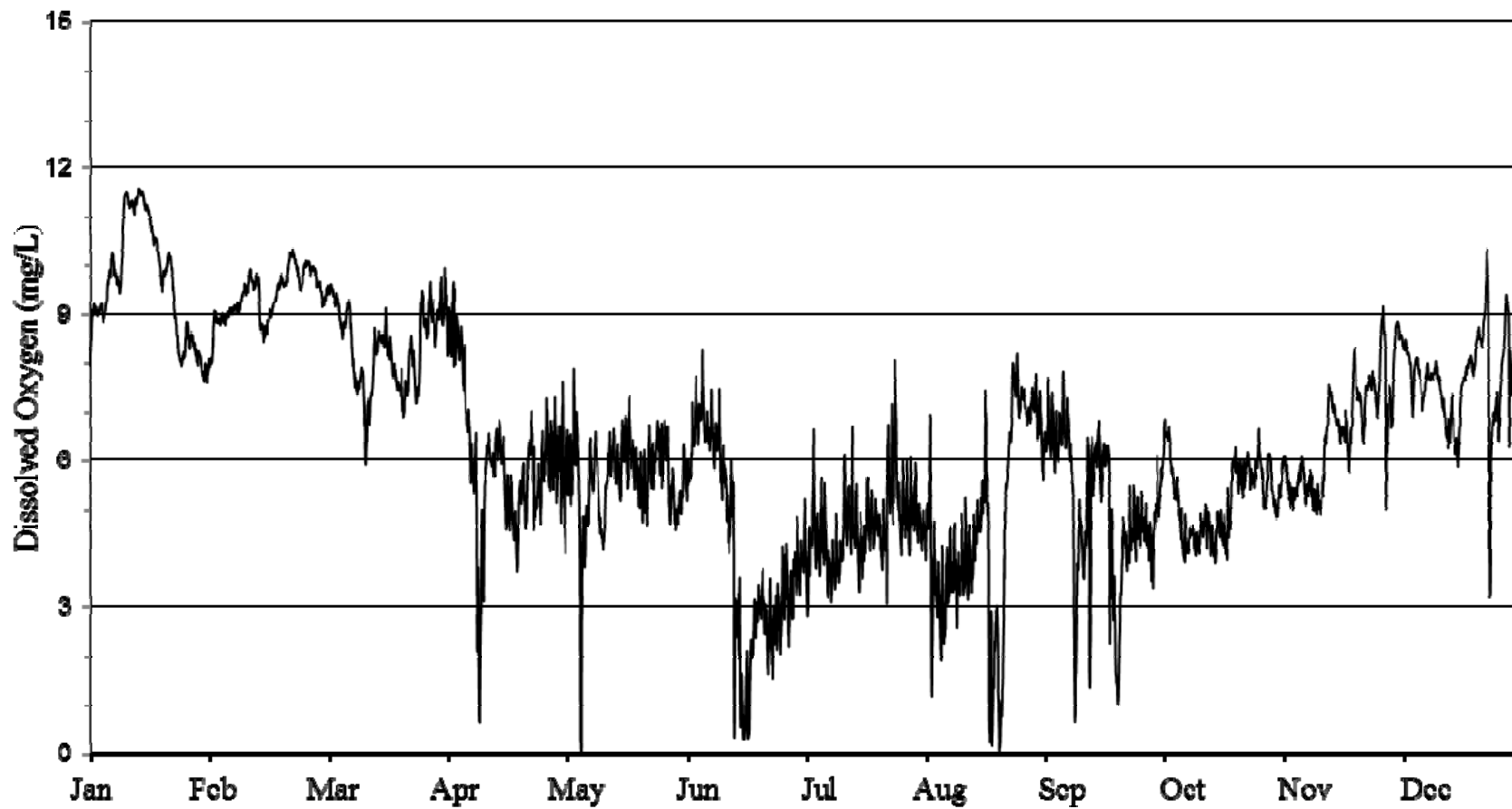


FIGURE 10: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT B&O CENTRAL RAILROAD ON THE CHICAGO SANITARY AND SHIP CANAL FROM JANUARY 1, 2015 THROUGH DECEMBER 31, 2015

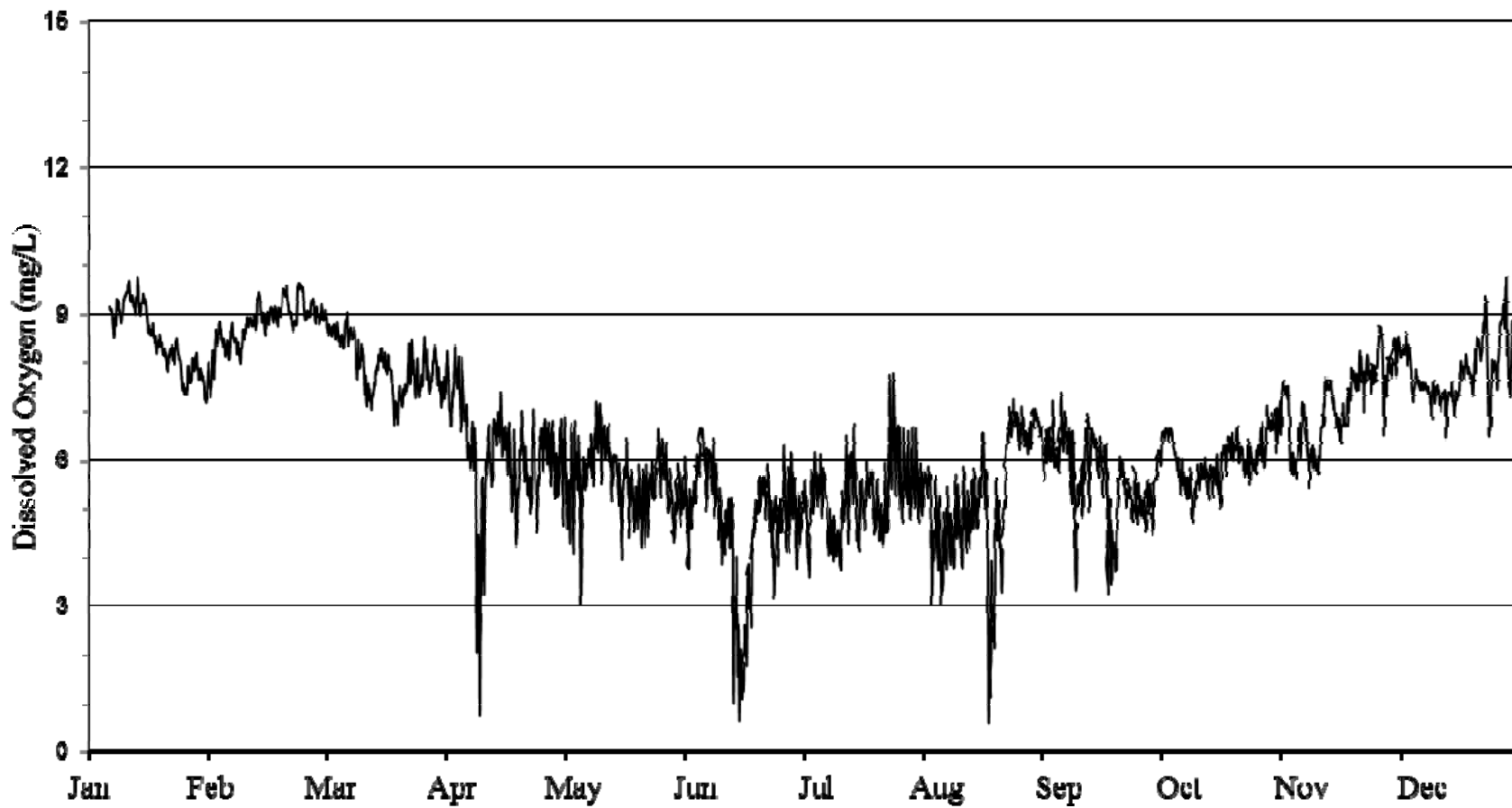


FIGURE 11: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT LOCKPORT POWERHOUSE ON THE CHICAGO SANITARY AND SHIP CANAL FROM JANUARY 1, 2015 THROUGH DECEMBER 31, 2015



FIGURE 12: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT C&W INDIANA RAILROAD ON THE LITTLE CALUMET RIVER FROM JANUARY 1, 2015 THROUGH DECEMBER 31, 2015

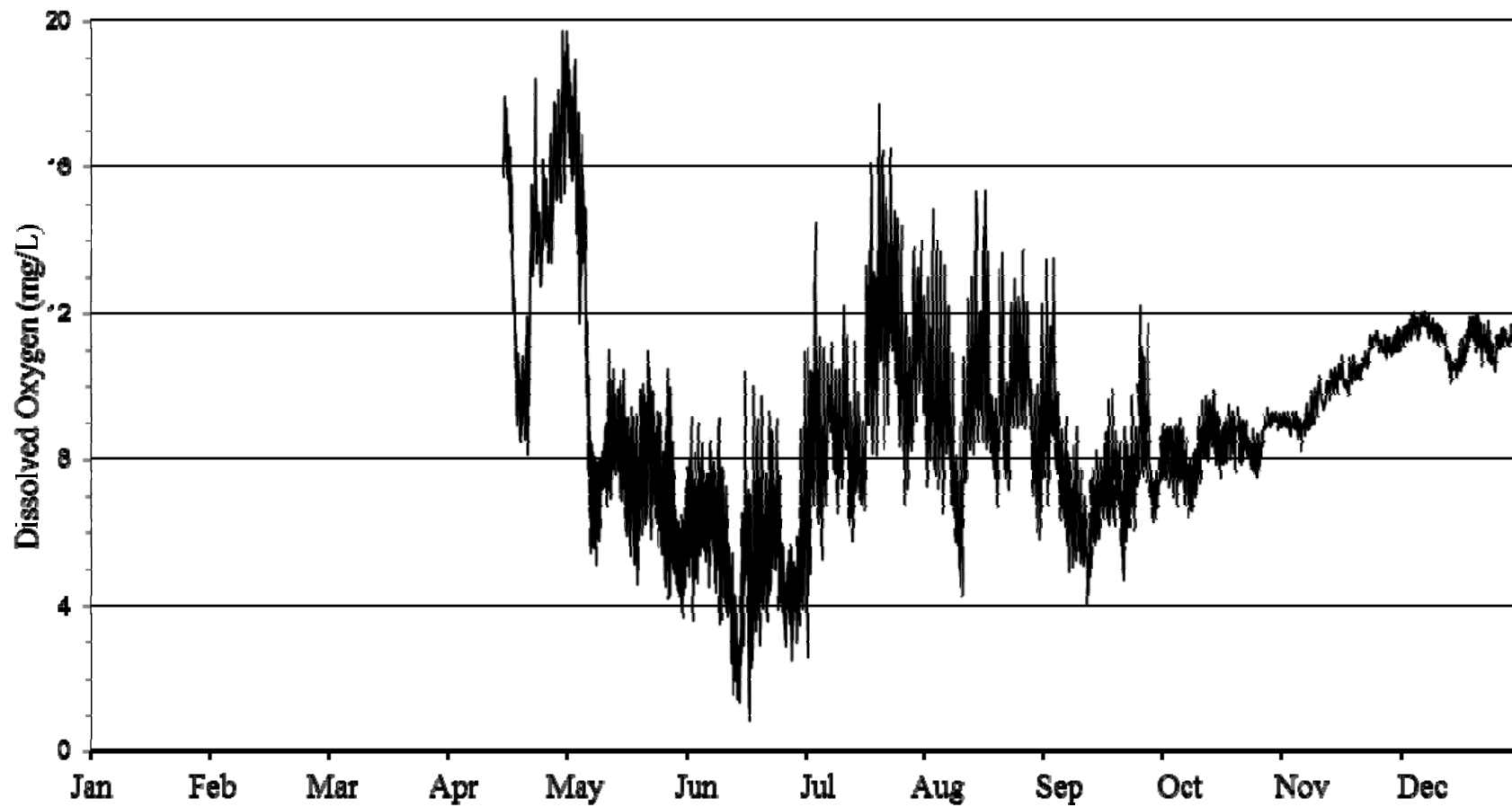


FIGURE 13: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT HALSTED STREET ON THE LITTLE CALUMET RIVER FROM JANUARY 1, 2015 THROUGH DECEMBER 31, 2015

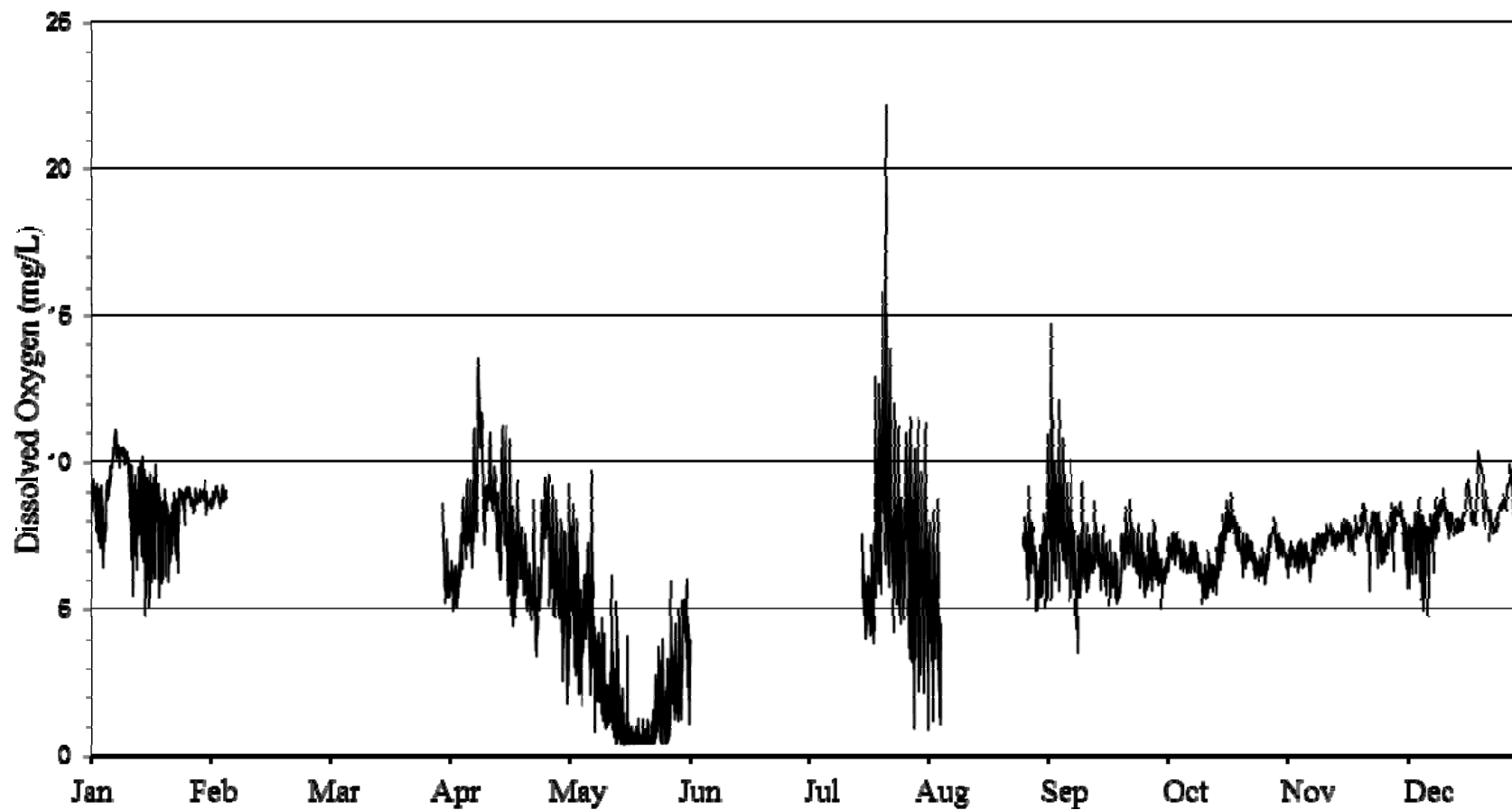


FIGURE 14: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT ASHLAND AVENUE ON THE LITTLE CALUMET RIVER FROM JANUARY 1, 2015 THROUGH DECEMBER 31, 2015

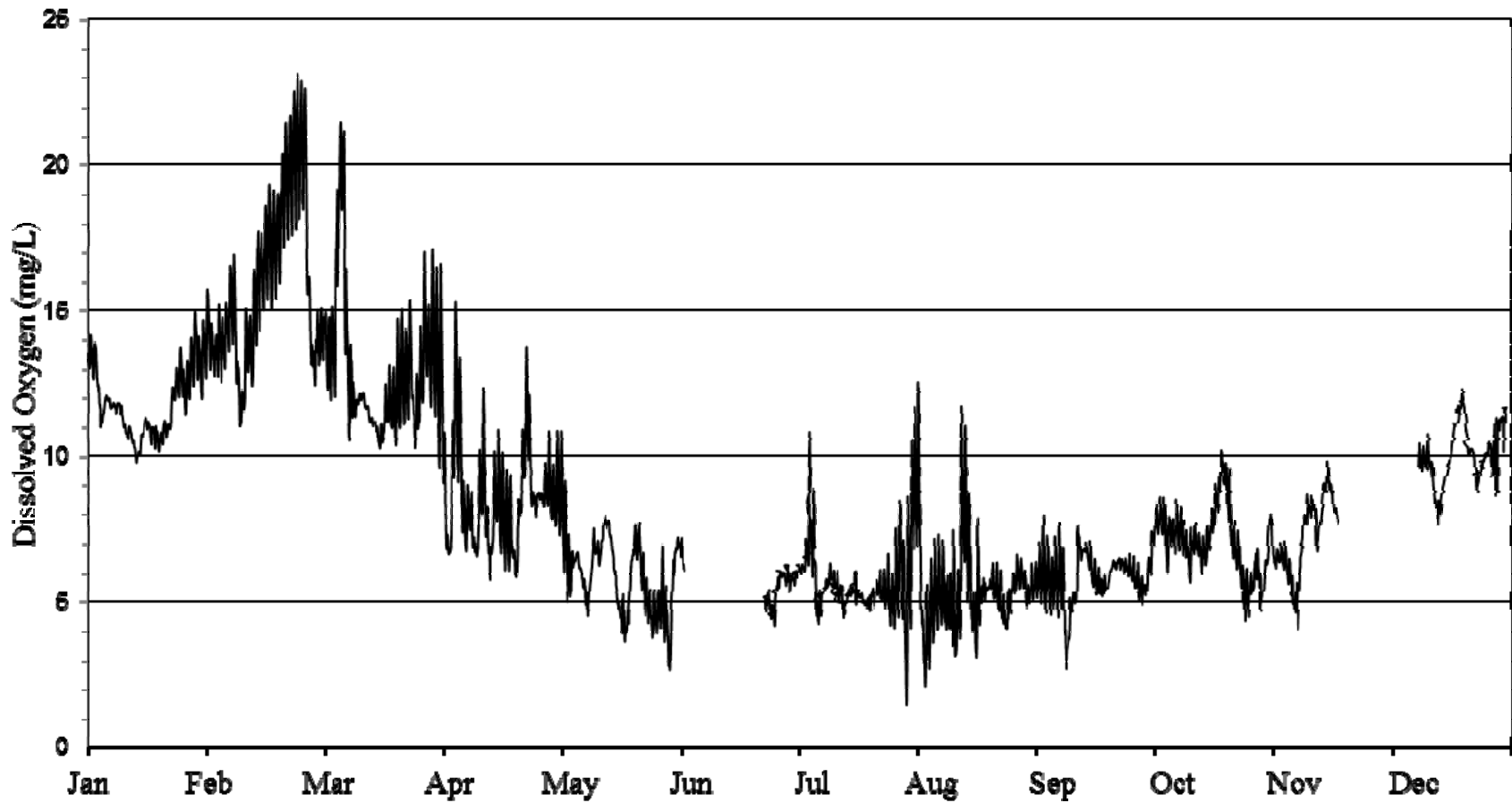


FIGURE 15: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT CICERO AVENUE ON THE CALUMET-SAG CHANNEL FROM JANUARY 1, 2015 THROUGH DECEMBER 31, 2015

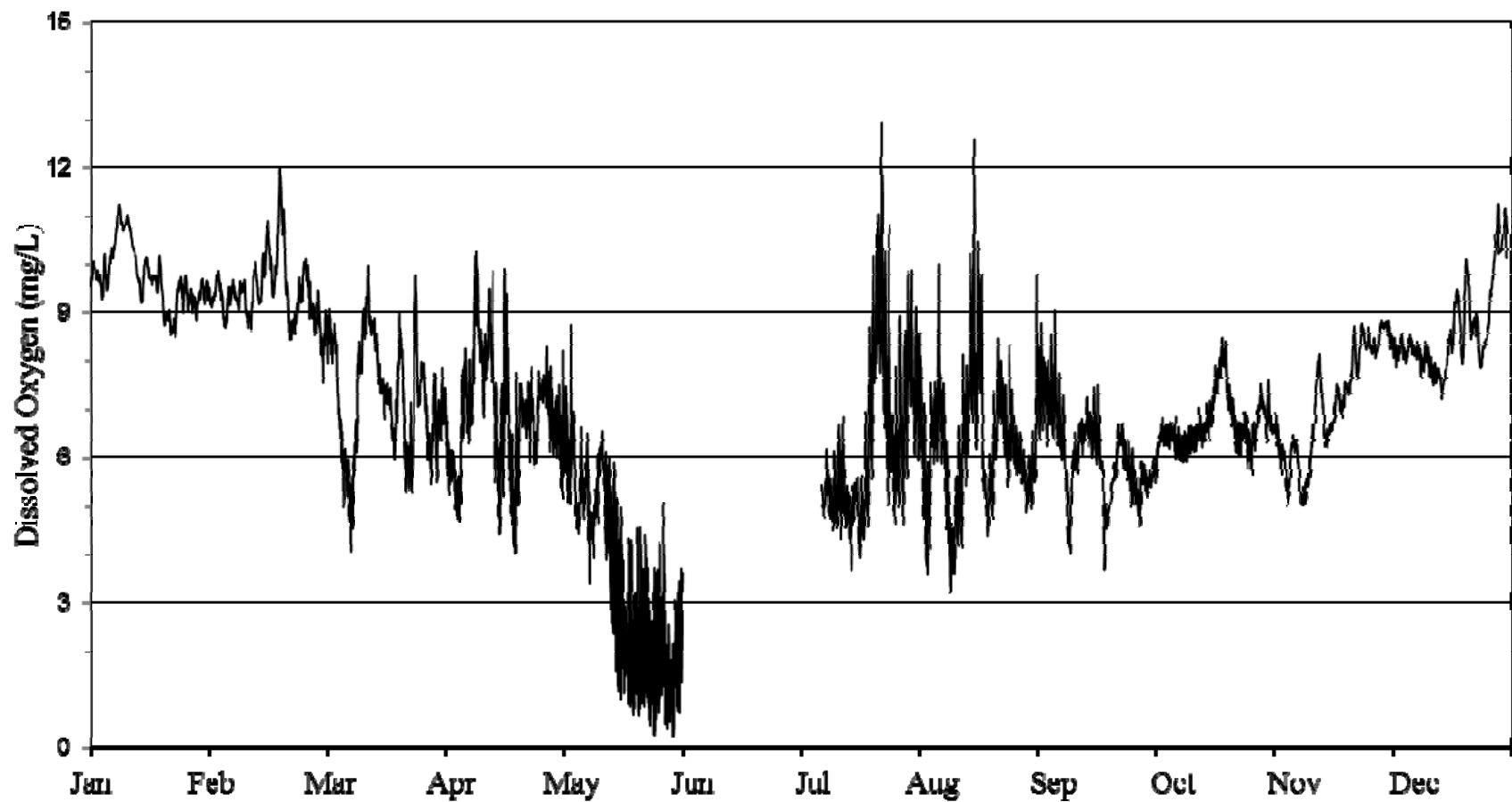


FIGURE 16: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT ROUTE 83 ON THE CALUMET-SAG CHANNEL FROM JANUARY 1, 2015 THROUGH DECEMBER 31, 2015

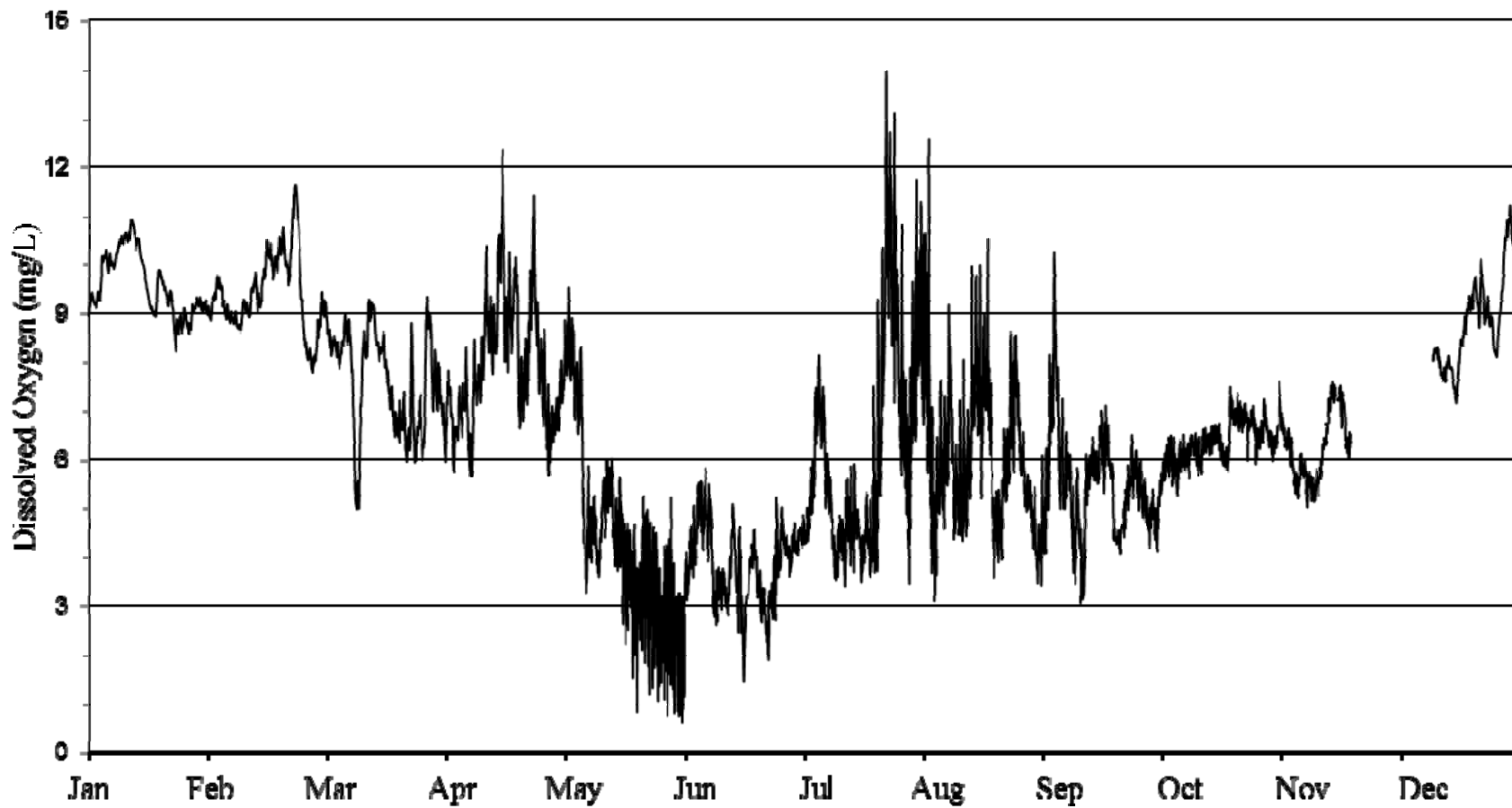


FIGURE 17: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT DEVON AVENUE ON THE DES PLAINES RIVER FROM JANUARY 1, 2015 THROUGH DECEMBER 31, 2015

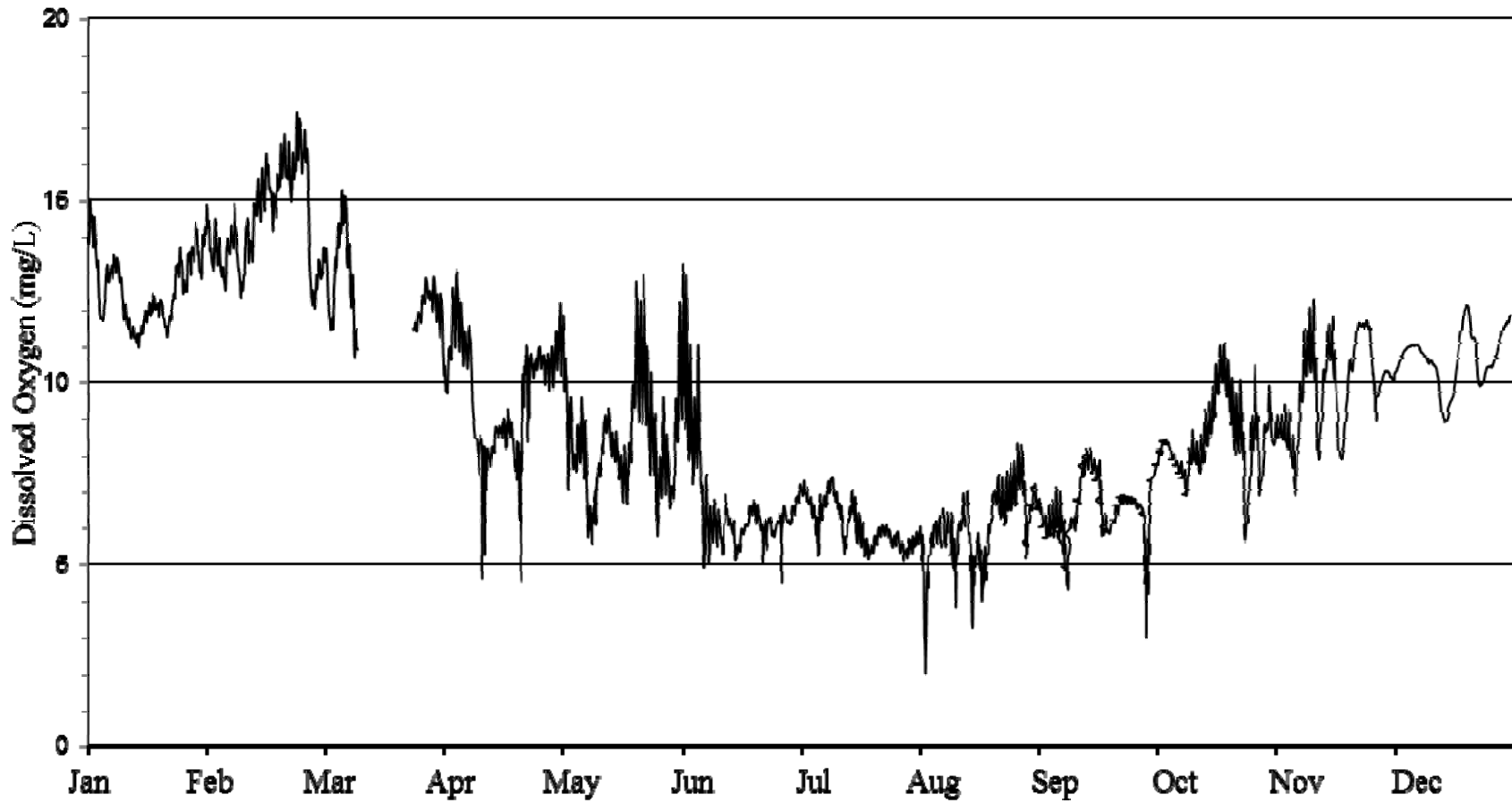


FIGURE 18: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT BUSSE LAKE DAM ON SALT CREEK FROM JANUARY 1, 2015 THROUGH DECEMBER 31, 2015

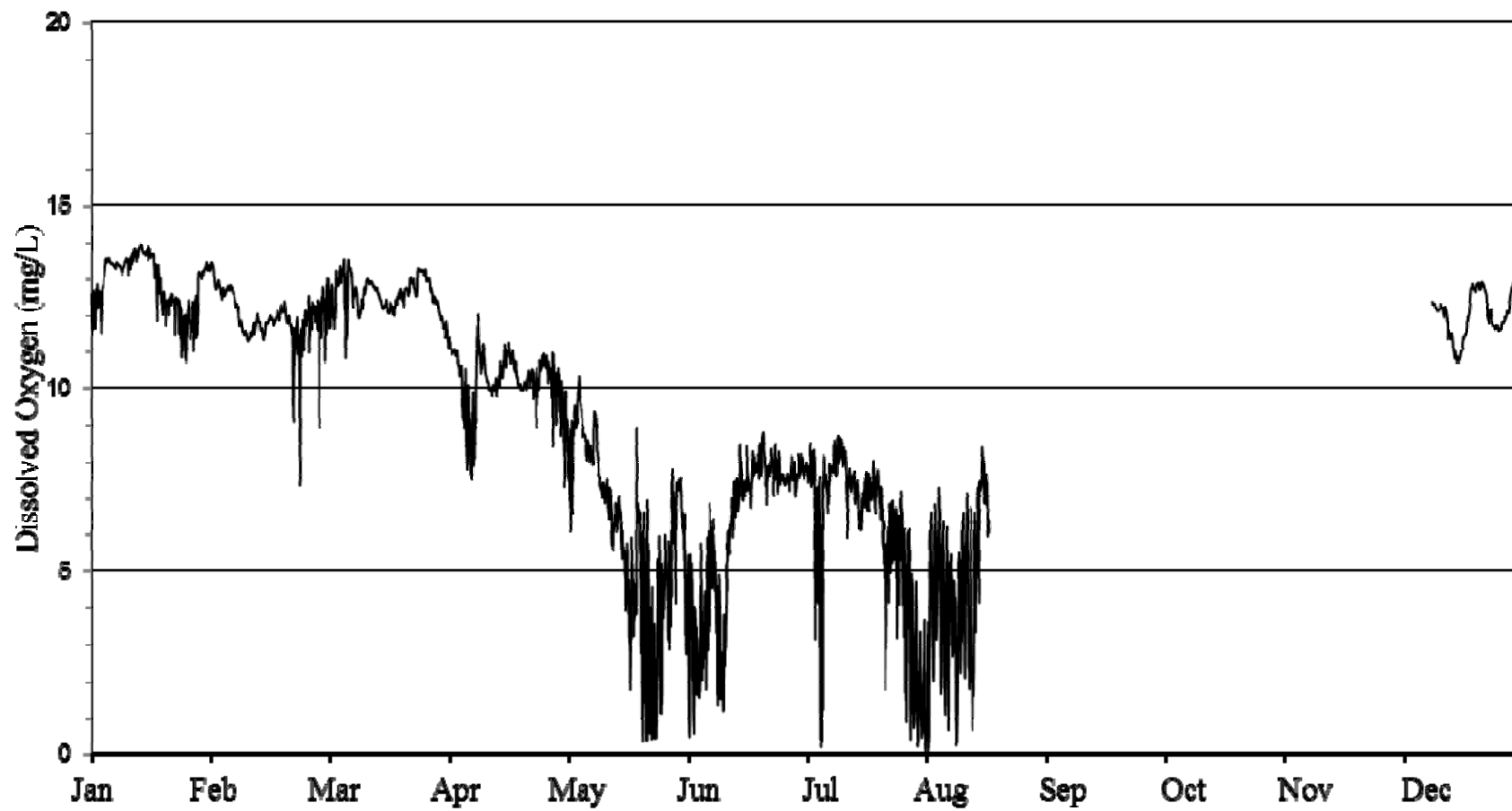


FIGURE 19: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT J.F. KENNEDY BOULEVARD ON SALT CREEK FROM JANUARY 1, 2015 THROUGH DECEMBER 31, 2015

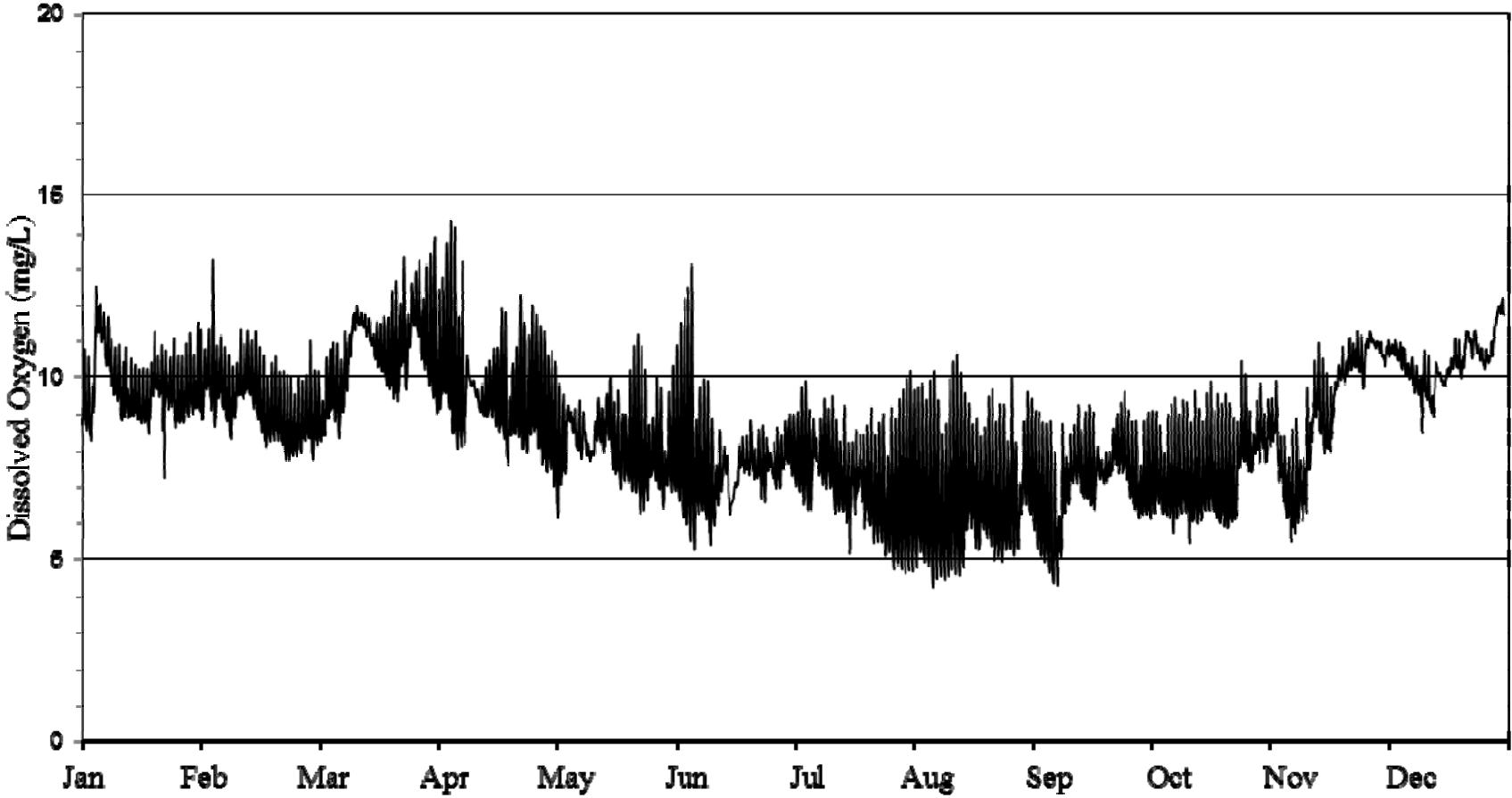
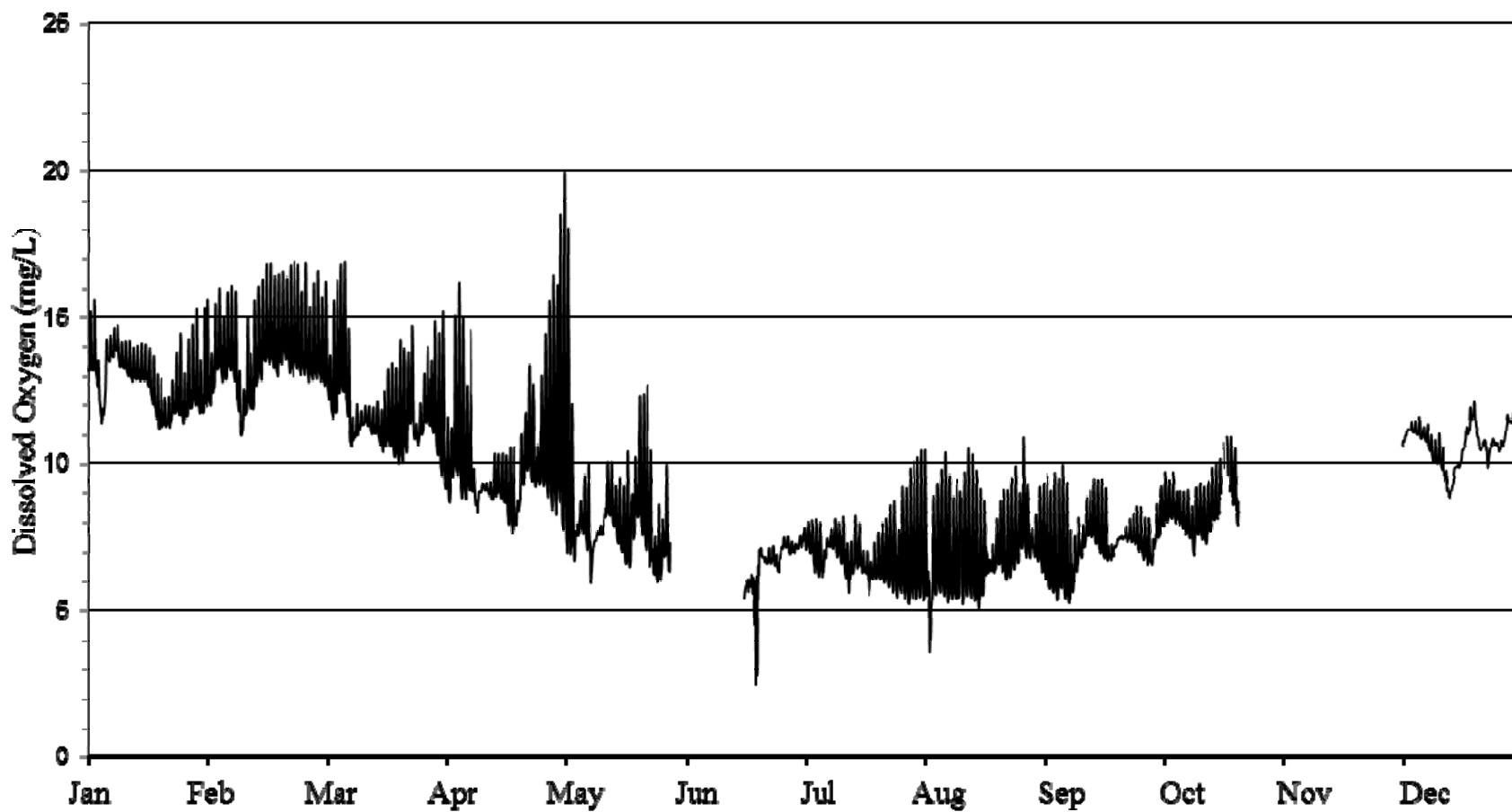


FIGURE 20: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT WOLF ROAD ON SALT CREEK FROM JANUARY 1, 2015 THROUGH DECEMBER 31, 2015



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 2015

TABLE A-1: SUMMARY STATISTICS FOR DISSOLVED OXYGEN MEASURED
DURING CROSS-SECTIONAL SURVEYS IN 2015

Waterway, Station, and Date	Water Depth ^a (ft.)			N ^b	Minimum (mg/L)	Maximum (mg/L)	Mean (mg/L)	Standard Deviation (mg/L)	Coefficient of Variation (%)
	Left	Center	Right						
<u>North Shore Channel</u>									
<u>Foster Avenue</u>									
06/12/2015	3.5	8.8	3.5	8	5.56	5.60	5.58	0.01	0.25
08/17/2015	2.5	9.7	4.4	9	6.17	6.48	6.25	0.13	2.04
10/16/2015	5.2	10.1	3.2	9	6.42	6.50	6.46	0.03	0.43
<u>North Branch Chicago River</u>									
<u>Addison Street</u>									
06/09/2015	7.9	8.7	4.7	10	6.24	6.39	6.28	0.05	0.78
09/01/2015	9.0	9.4	6.0	12	7.46	7.58	7.53	0.04	0.53
10/15/2015	8.4	8.5	4.2	11	6.28	6.37	6.33	0.03	0.49
<u>Division Street</u>									
06/09/2015	11.0	17.0	16.7	12	7.16	7.55	7.28	0.10	1.42
09/01/2015	14.7	17.9	11.9	12	6.83	7.22	7.09	0.13	1.82
10/15/2015	11.2	17.1	15.4	12	4.05	4.34	4.28	0.08	1.90
<u>Chicago River</u>									
<u>Clark Street</u>									
06/09/2015	12.5	24.2	19.0	12	8.96	9.24	9.10	0.09	0.98
09/01/2015	14.2	25.0	19.9	12	8.86	10.04	9.38	0.28	2.94
10/15/2015	12.4	24.3	19.2	12	7.74	7.97	7.89	0.08	1.03

TABLE A-1 (Continued): SUMMARY STATISTICS FOR DISSOLVED OXYGEN MEASURED
DURING CROSS-SECTIONAL SURVEYS IN 2015

Waterway, Station, and Date	Water Depth ^a (ft.)			N ^b	Minimum (mg/L)	Maximum (mg/L)	Mean (mg/L)	Standard Deviation (mg/L)	Coefficient of Variation (%)
	Left	Center	Right						
<u>South Branch Chicago River</u>									
<u>Loomis Street</u>									
05/27/2015	20.4	23.6	17.0	12	6.59	7.15	6.81	0.14	2.03
08/19/2015	21.5	22.4	17.3	12	5.01	5.10	5.05	0.03	0.52
10/21/2015	17.9	21.5	16.2	12	6.83	6.91	6.87	0.03	0.39
<u>Bubbly Creek</u>									
<u>36th Street</u>									
05/27/2015	4.5	5.1	5.2	9	1.33	2.01	1.61	0.21	13.21
08/20/2015	2.7	5.0	5.5	8	0.00	0.01	0.001	0.004	282.84
10/21/2015	4.1	5.1	4.9	9	9.64	9.95	9.79	0.11	1.16
<u>Interstate Highway 55</u>									
05/27/2015	4.7	10.3	9.0	11	3.57	5.42	4.07	0.54	13.21
08/20/2015	5.1	10.9	9.4	11	0.00	0.07	0.006	0.02	331.66
10/21/2015	10.5	11.1	7.1	11	5.46	5.74	5.67	0.08	1.32
<u>Chicago Sanitary and Ship Canal</u>									
<u>Cicero Avenue</u>									
05/27/2015	14.3	18.7	7.6	11	6.00	7.32	6.36	0.37	5.87
08/20/2015	13.0	17.3	8.1	12	2.71	2.80	2.75	0.03	1.05
10/21/2015	13.8	19.3	10.6	12	5.27	5.42	5.37	0.05	0.90

TABLE A-1 (Continued): SUMMARY STATISTICS FOR DISSOLVED OXYGEN MEASURED DURING CROSS-SECTIONAL SURVEYS IN 2015

Waterway, Station, and Date	Water Depth ^a (ft.)			N ^b	Minimum (mg/L)	Maximum (mg/L)	Mean (mg/L)	Standard Deviation (mg/L)	Coefficient of Variation (%)
	Left	Center	Right						
<u>Chicago Sanitary and Ship Canal (Continued)</u>									
<u>B&O Railroad</u>									
06/18/2015	9.5	16.1	10.5	12	3.20	3.54	3.31	0.11	3.41
08/20/2015	14.7	19.7	5.6	11	2.88	3.06	3.00	0.07	2.49
10/21/2015	14.1	20.6	9.1	12	5.99	6.46	6.23	0.15	2.40
<u>Lockport Powerhouse</u>									
05/29/2015	28.5	28.3	30.2	12	3.96	4.16	4.03	0.05	1.21
08/13/2015	27.5	28.6	29.7	12	3.49	3.92	3.62	0.13	3.48
10/02/2015	28.7	29.0	30.4	12	4.75	5.80	5.11	0.30	5.78
<u>Little Calumet River</u>									
<u>C&W Indiana Railroad</u>									
06/02/2015	8.9	14.7	8.9	12	7.40	8.13	7.75	0.27	3.47
08/28/2015	8.9	15.3	7.1	11	10.80	11.61	11.37	0.22	1.97
10/06/2015	7.1	15.7	9.2	11	8.86	9.20	9.02	0.15	1.61
<u>Halsted Street</u>									
06/02/2015	2.8	14.5	4.3	9	4.29	5.00	4.55	0.30	6.49
08/26/2015	5.4	14.4	4.8	10	7.45	7.94	7.66	0.16	2.08
10/06/2015	6.4	14.6	3.2	9	7.12	7.26	7.21	0.05	0.71

TABLE A-1 (Continued): SUMMARY STATISTICS FOR DISSOLVED OXYGEN MEASURED DURING CROSS-SECTIONAL SURVEYS IN 2015

Waterway, Station, and Date	Water Depth ^a (ft.)			N ^b	Minimum (mg/L)	Maximum (mg/L)	Mean (mg/L)	Standard Deviation (mg/L)	Coefficient of Variation (%)
	Left	Center	Right						
<u>Little Calumet River (Continued)</u>									
<u>Ashland Avenue</u>									
05/21/2015	1.6	3.0	2.3	6	7.71	8.35	7.96	0.28	3.46
08/07/2015	1.8	2.5	2.1	6	4.44	4.75	4.59	0.13	2.78
10/02/2015	2.3	2.8	2.7	6	7.30	8.31	7.66	0.35	4.51
<u>Calumet-Sag Channel</u>									
<u>Cicero Avenue</u>									
06/02/2015	8.9	13.1	9.9	12	5.70	6.02	5.86	0.09	1.56
08/26/2015	10.6	13.1	9.1	12	7.00	7.36	7.16	0.11	1.59
10/06/2015	8.0	14.1	8.8	12	6.76	6.84	6.79	0.03	0.37
<u>Route 83</u>									
06/02/2015	15.9	13.4	10.2	12	3.80	4.04	3.89	0.07	1.86
08/28/2015	12.6	13.3	10.5	12	5.48	5.82	5.62	0.11	1.92
10/06/2015	15.6	13.3	9.1	12	5.94	6.13	6.05	0.05	0.75
<u>Des Plaines River</u>									
<u>Devon Avenue</u>									
05/22/2015	1.4	2.6	2.0	5	11.14	11.27	11.22	0.05	0.47
08/03/2015	1.7	2.7	1.9	6	3.15	3.27	3.19	0.04	1.37
10/14/2015	1.6	2.4	1.3	6	7.93	8.23	8.06	0.13	1.64

TABLE A-1 (Continued): SUMMARY STATISTICS FOR DISSOLVED OXYGEN MEASURED DURING CROSS-SECTIONAL SURVEYS IN 2015

Waterway, Station, and Date	Water Depth ^a (ft.)			N ^b	Minimum (mg/L)	Maximum (mg/L)	Mean (mg/L)	Standard Deviation (mg/L)	Coefficient of Variation (%)
	Left	Center	Right						
<u>Salt Creek</u>									
<u>Busse Lake Dam</u>									
05/22/2015	2.0	2.7	1.8	6	9.26	9.57	9.36	0.14	1.47
08/03/2015	2.2	4.1	2.7	7	7.89	7.96	7.91	0.03	0.33
<u>J.F. Kennedy Boulevard</u>									
05/22/2015	0.6	1.2	2.0	4	9.71	10.05	9.87	0.16	1.62
08/03/2015	2.2	3.3	3.6	6	7.48	7.72	7.58	0.11	1.40
10/14/2015	0.5	1.4	2.0	5	6.98	7.05	7.01	0.03	0.43
<u>Wolf Road</u>									
05/22/2015	1.3	1.8	1.3	6	10.10	10.83	10.42	0.29	2.74
08/03/2015	1.6	3.2	2.9	6	6.17	6.26	6.21	0.03	0.53
10/14/2015	1.1	1.4	1.1	6	9.32	9.74	9.56	0.18	1.88

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

^bNumber of dissolved oxygen measurements across transects.