Metropolitan Water Reclamation District of Greater Chicago

MONITORING AND RESEARCH DEPARTMENT

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CONTINUOUS DISSOLVED OXYGEN MONITORING IN THE CHICAGO AREA WATERWAYS DURING 2014

October 2015

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CONTINUOUS DISSOLVED OXYGEN MONITORING IN THE CHICAGO AREA WATERWAYS DURING 2014

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LIST OF ACRONYMS

Abbreviation/Acronym	Definition
CAWS	Chicago Area Waterway System
CDOM	Continuous Dissolved Oxygen Monitoring
CRS	Chicago River System
CSO	Combined Sewer Overflow
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
M&R	Monitoring and Research Department
Monitor	Continuous Water Quality Monitor
MWRD*	Metropolitan Water Reclamation District of Greater Chicago*
O'Brien	Terrence J. O'Brien
RR	Railroad
SEPA	Sidestream Elevated Pool Aeration Station
USEPA	United States Environmental Protection Agency
WRP	Water Reclamation Plant
YSI	YSI Incorporated

*See map on page 4

ACKNOWLEDGMENT

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Particular thanks are due to Marie Biron 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).

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. The duration of the monitoring program was extended and the scope was expanded to include the Calumet River System in 2001, and then 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 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, 2014 through December 31, 2014 for the deep-draft waterways and wadeable streams within the Chicago Metropolitan area.

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. All of the 2014 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 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 (CSSC), two locations in the Little Calumet River, and two locations in the Calumet-Sag Channel.

There are five stations in the Chicago Metropolitan Area Wadeable Streams. Four wadeable monitoring stations were located in the Upper Des Plaines River System. One site was on the Upper Des Plaines River and three sites were on Salt Creek. One wadeable monitoring station is in the Calumet River System on the Little Calumet River.

Effective March 4, 2014, the CDOM station at Cicero Avenue on the Calumet-Sag Channel was reactivated.

Designated Uses for 2014

The IPCB has assigned water uses for specific water bodies within the state of Illinois. All waters in Illinois are designated for General Use, except those selected as Secondary Contact and Indigenous Aquatic Life Waters (Secondary Contact). In the Chicago and Calumet River Systems, General Use Waters include the North Shore Channel from Lake Michigan to the O'Brien WRP, and the Chicago and Calumet Rivers. Secondary Contact Waters include the North Shore Channel from the O'Brien WRP to the North Branch Chicago River, the North Branch of the Chicago River from the North Shore Channel to the Chicago River, the South Branch of the Chicago River, Bubbly Creek, the CSSC, the Grand Calumet River, the deep-draft portion of the Little Calumet River, the Calumet-Sag Channel, and the Des Plaines River from its confluence with the CSSC to the Interstate Highway 55 bridge southwest of Joliet.

Dissolved Oxygen Water Quality Standards for 2014

The IPCB has established water quality standards for DO in both General Use and Secondary Contact Waters. In Secondary Contact Waters, the DO shall not be less than 4.0 mg/L at any time, except in the Calumet-Sag Channel, where the DO shall not be less than 3.0 mg/L at any time, and in the portion of the North Shore Channel from the O'Brien WRP to the

North Branch Chicago River, where the DO shall not be less than 5.0 mg/L for 16 hours of any 24-hour period nor less than 4.0 mg/L at any time. 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: 2014 CONTINUOUS DISSOLVED OXYGEN MONITORING STATIONS

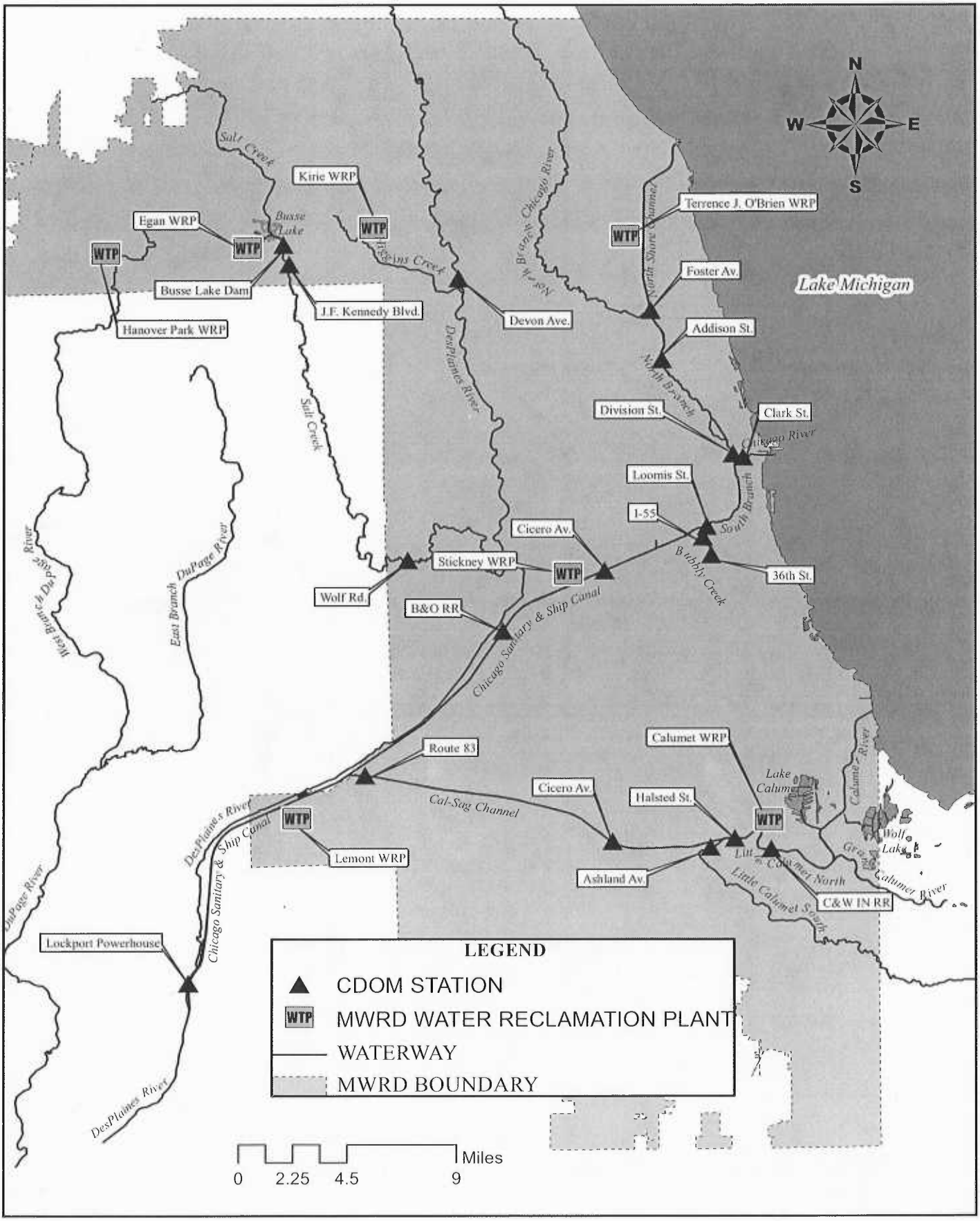


TABLE 1: CONTINUOUS DISSOLVED OXYGEN MONITORING STATIONS DURING 2014

Monitoring Station	Waterway	Description of Monitoring Station
	Chicago River System	
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 2014

Monitoring Station	Waterway	Description of Monitoring Station
	Chicago River System (Continued)	
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.
	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.

TABLE 1 (Continued): CONTINUOUS DISSOLVED OXYGEN MONITORING STATIONS DURING 2014

Monitoring Station	Waterway	Description of Monitoring Station
	Calumet River System (Continued)	
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 2014

Monitoring Station	Waterway	Description of Monitoring Station
	Des Plaines River System (Continued)	
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.

[1]RR=Railroad
[2]SEPA=Sidestream Elevated Pool Aeration Station

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 in the field in 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 14-21 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 directly exported electronically from individual monitors to a specially designed Oracle® 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, as well as considering the historical profile for a given monitoring station. Errors most often are 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 2014, 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 side 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 2014 are shown in Table 2.

The number and percent of measured DO concentrations rejected and removed from the Oracle® database following review during 2014 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 2014 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 2014

Monitoring Station	Waterway	DO Concentration (mg/L) Minimum	Maximum	Mean
	Chicago River System			
Foster Avenue	North Shore Channel	1.9	13.1	7.5
Addison Street	North Branch Chicago River	1.1	12.9	7.4
Division Street	North Branch Chicago River	0.3	13.3	7.3
Clark Street	Chicago River	0.2	12.7	9.0
Loomis Street	South Branch Chicago River	0.2	12.7	7.3
36th Street	Bubbly Creek	0.0	25.1	4.7
Interstate Highway 55	Bubbly Creek	0.0	14.6	4.3
Cicero Avenue	Chicago Sanitary and Ship Canal	0.0	12.1	6.1
B&O Central Railroad	Chicago Sanitary and Ship Canal	0.4	10.4	6.6
Lockport Powerhouse	Chicago Sanitary and Ship Canal	0.0	9.6	5.4
	Calumet River System			
C&W Indiana Railroad	Little Calumet River	0.2	19.8	8.7
Halsted Street	Little Calumet River	0.8	13.7	6.9
Ashland Avenue	Little Calumet River	0.2	14.4	8.5
Cicero Avenue	Calumet-Sag Channel	0.6	12.2	6.5
Route 83	Calumet-Sag Channel	0.4	12.4	6.8
	Des Plaines River System			
Devon Avenue	Des Plaines River	4.4	14.8	9.3
Busse Lake Dam	Salt Creek	0.5	15.1	10.1
J.F. Kennedy Boulevard	Salt Creek	2.8	13.9	8.5
Wolf Road	Salt Creek	1.6	17.5	9.3

TABLE 3: NUMBER AND PERCENT OF DISSOLVED OXYGEN VALUES NOT MEETING ACCEPTANCE CRITERIA DURING 2014

Monitoring Station	Waterway	Number of DO Values Rejected	Percent of DO Values Rejected
	Chicago River System		
Foster Avenue	North Shore Channel	1,515	17[a]
Addison Street	North Branch Chicago River	312	4[b]
Division Street	North Branch Chicago River	337	4[c]
Clark Street	Chicago River	384	4[d]
Loomis Street	South Branch Chicago River	0	0
36th Street	Bubbly Creek	1,275	15[e]
Interstate Highway 55	Bubbly Creek	0	0
Cicero Avenue	Chicago Sanitary and Ship Canal	0	0
B&O Central Railroad	Chicago Sanitary and Ship Canal	829	9[f]
Lockport Powerhouse	Chicago Sanitary and Ship Canal	0	0
	Calumet River System		
C&W Indiana Railroad	Little Calumet River	1,884	22[g]
Halsted Street	Little Calumet River	1,058	12[h]
Ashland Avenue	Little Calumet River	671	8[i]
Cicero Avenue[j]	Calumet-Sag Channel	335	5[k]
Route 83	Calumet-Sag Channel	336	4[l]
	Des Plaines River System		
Devon Avenue	Des Plaines River	374	4[m]
Busse Lake Dam	Salt Creek	651	7[n]
J.F. Kennedy Boulevard	Salt Creek	371	4[o]
Wolf Road	Salt Creek	1,293	15[p]

[a] 1/14 - 2/25/14 monitor failed criteria 2 and 3. 10/23 – 11/13/14 monitor failed criteria 2 and 3.
[b] 3/12 – 3/25/14 monitor failed criterion 1.
[c] 7/3 – 7/17/14 monitor failed criterion 1.
[d] 10/7 – 10/23/14 equipment failure.
[e] 5/15 – 6/11/14, 7/11 - 7/23/14 monitor failed criteria 2 and 3. 7/23 – 8/6/14 monitor failed criterion 1.
[f] 2/20 – 3/4/14 monitor failed criterion 1. 12/9 – 12/31/14 monitor failed criteria 1 and 3.
[g] 5/13 – 5/28/14, 6/10 – 6/25/14, 10/1 - 11/5/14, 12/18 – 12/31/14 monitor failed criteria 2 and 3.
[h] 4/17 – 5/1/14, 5/13 – 5/28/14 equipment failure. 6/10 – 6/25/14 monitor failed criteria 2 and 3.
[i] 4/2 – 4/16/14 monitor failed criteria 2 and 3. 7/23 – 8/6/14 equipment failure.
[j] Data collection started 3/4/14.
[k] 4/17 – 5/1/14 monitor failed criteria 2 and 3.
[l] 6/25 - 7/9/14 monitor failed criterion 1.
[m] 1/1 – 1/16/14 monitor failed criterion 1.
[n] 5/22 – 6/4/14 monitor failed criteria 2 and 3. 6/18 – 7/2/14 monitor failed criterion 1.
[o] 1/1 – 1/16/14 monitor failed criterion 1.
[p] 1/16 – 3/11/14 monitor failed criterion 1.

TABLE 4: PERCENT OF DISSOLVED OXYGEN VALUES IN SELECTED RANGES DURING 2014

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											
Foster Avenue	North Shore Channel	0	<1	<1	<1	<1	4	28	41	20	4	2
Addison Street	North Branch Chicago River	0	<1	<1	<1	1	8	34	27	18	9	3
Division Street	North Branch Chicago River	<1	<1	<1	<1	3	11	30	26	20	7	3
Clark Street	Chicago river	<1	<1	<1	<1	2	2	6	14	20	23	32
Loomis Street	South Branch Chicago River	<1	<1	2	3	5	17	19	20	9	11	12
36th Street	Bubbly Creek	51	4	4	4	4	3	3	3	3	3	18
Interstate Highway 55	Bubbly Creek	29	6	6	7	7	10	10	7	7	4	7
Cicero Avenue	Chicago Sanitary and Ship Canal	4	4	6	10	11	11	12	12	14	13	2
B&O Central Railroad	Chicago Sanitary and Ship Canal	<1	1	2	5	15	21	14	10	18	14	<1
Lockport Powerhouse	Chicago Sanitary and Ship Canal	2	4	11	16	14	10	12	17	12	2	0
	Calumet River System											
C&W Indiana Railroad	Little Calumet River	<1	<1	<1	2	4	8	11	10	14	15	34
Halsted Street	Little Calumet River	<1	<1	<1	2	9	18	19	25	23	4	<1
Ashland Avenue	Little Calumet River	2	<1	<1	1	6	15	17	11	5	4	40
Cicero Avenue[b]	Calumet-Sag Channel	<1	<1	1	5	16	26	16	8	18	9	2
Route 83	Calumet-Sag Channel	<1	<1	3	9	12	13	13	14	21	11	4
	Des Plaines River System											
Devon Avenue	Des Plaines River	0	0	0	0	<1	10	17	11	9	8	44
Busse Lake Dam	Salt Creek	<1	<1	<1	<1	<1	1	4	14	13	12	53
J.F. Kennedy Boulevard	Salt Creek	0	0	<1	<1	2	6	13	18	22	17	22
Wolf Road	Salt Creek	0	<1	<1	<1	<1	4	18	15	14	11	38

[a]Percentages greater than one are rounded to nearest whole number.
[b]Data collection started March 4, 2014.

FIGURE 2: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT FOSTER AVENUE ON THE NORTH SHORE CHANNEL FROM JANUARY 1, 2014 THROUGH DECEMBER 31, 2014

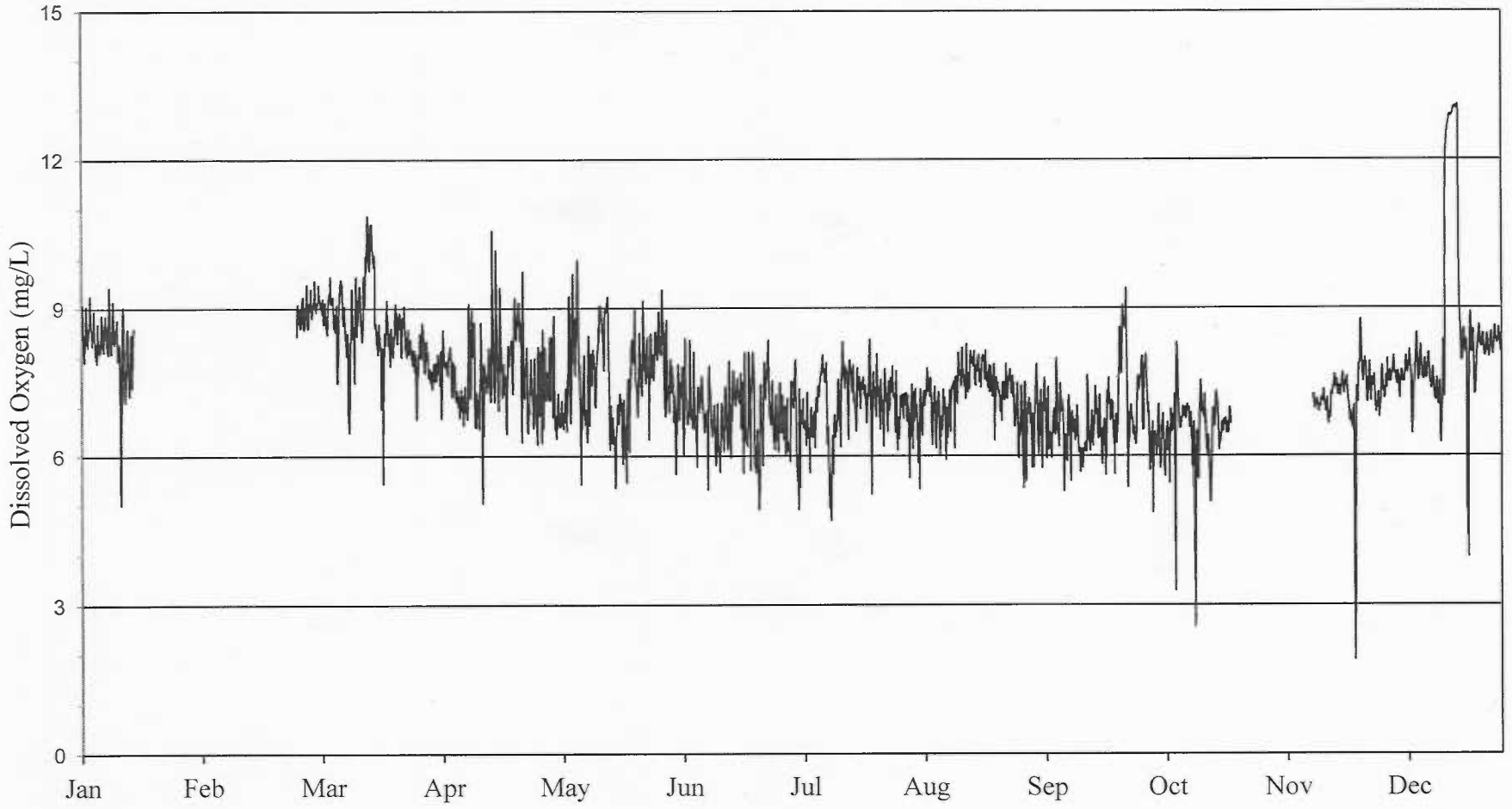


FIGURE 3: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT ADDISON STREET
ON THE NORTH BRANCH CHICAGO RIVER FROM JANUARY 1, 2014 THROUGH DECEMBER 31, 2014

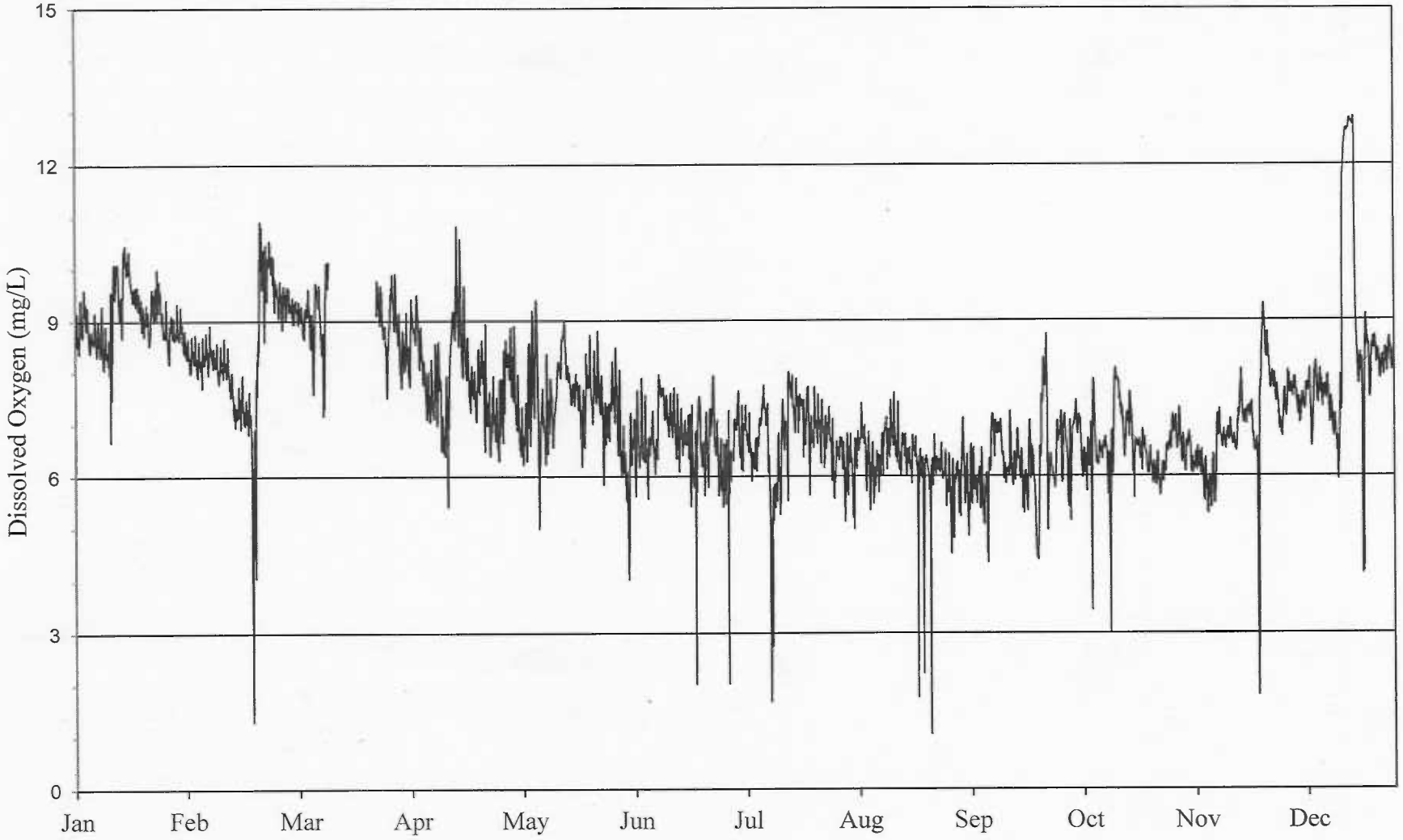


FIGURE 4: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT DIVISION STREET
ON THE NORTH BRANCH CHICAGO RIVER FROM JANUARY 1, 2014 THROUGH DECEMBER 31, 2014

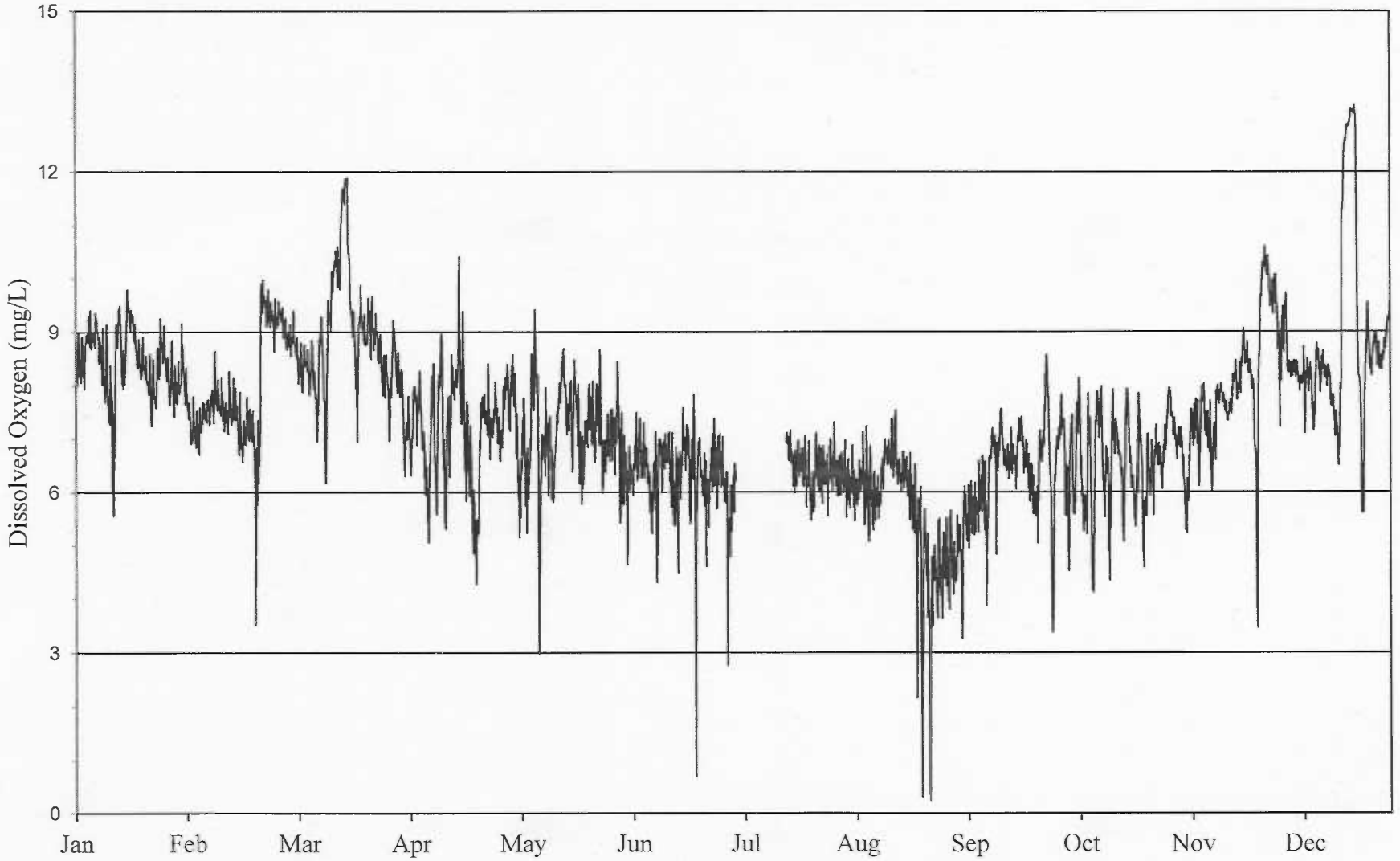


FIGURE 5: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT CLARK STREET ON THE CHICAGO RIVER FROM JANUARY 1, 2014 THROUGH DECEMBER 31, 2014

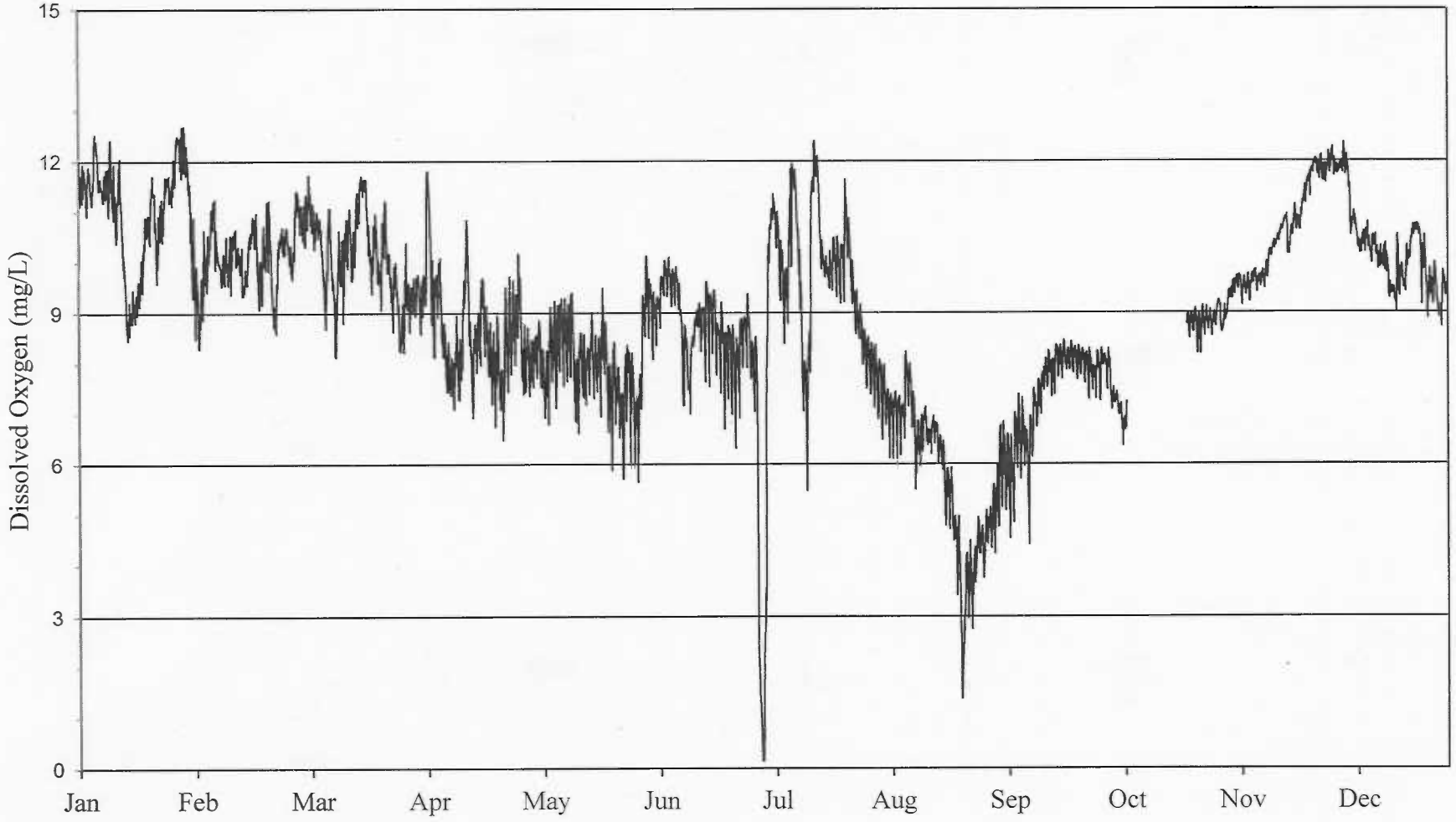


FIGURE 6: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT LOOMIS STREET ON THE SOUTH BRANCH CHICAGO RIVER FROM JANUARY 1, 2014 THROUGH DECEMBER 31, 2014

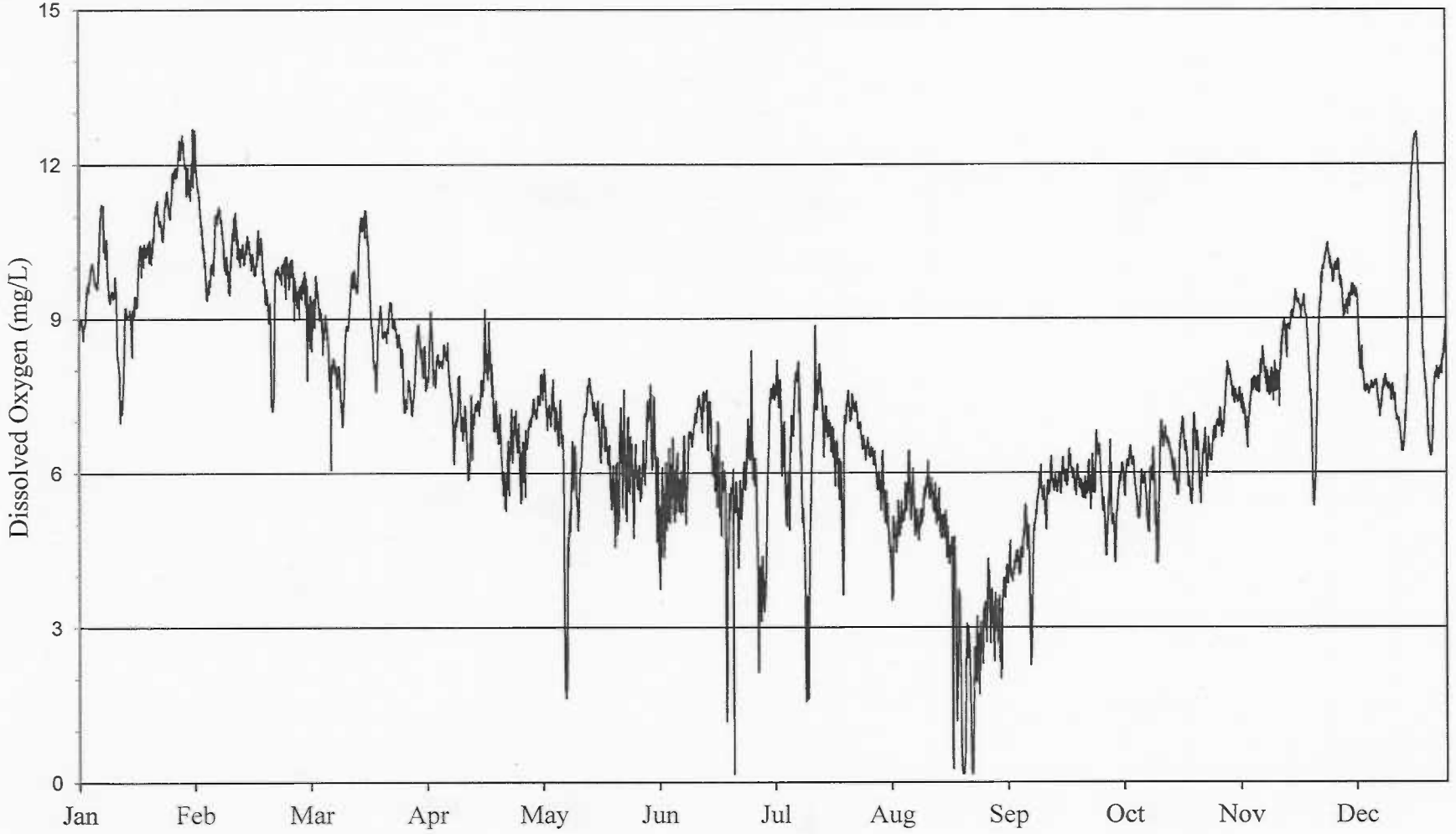


FIGURE 7: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT 36th STREET ON BUBBLY CREEK FROM JANUARY 1, 2014 THROUGH DECEMBER 31, 2014

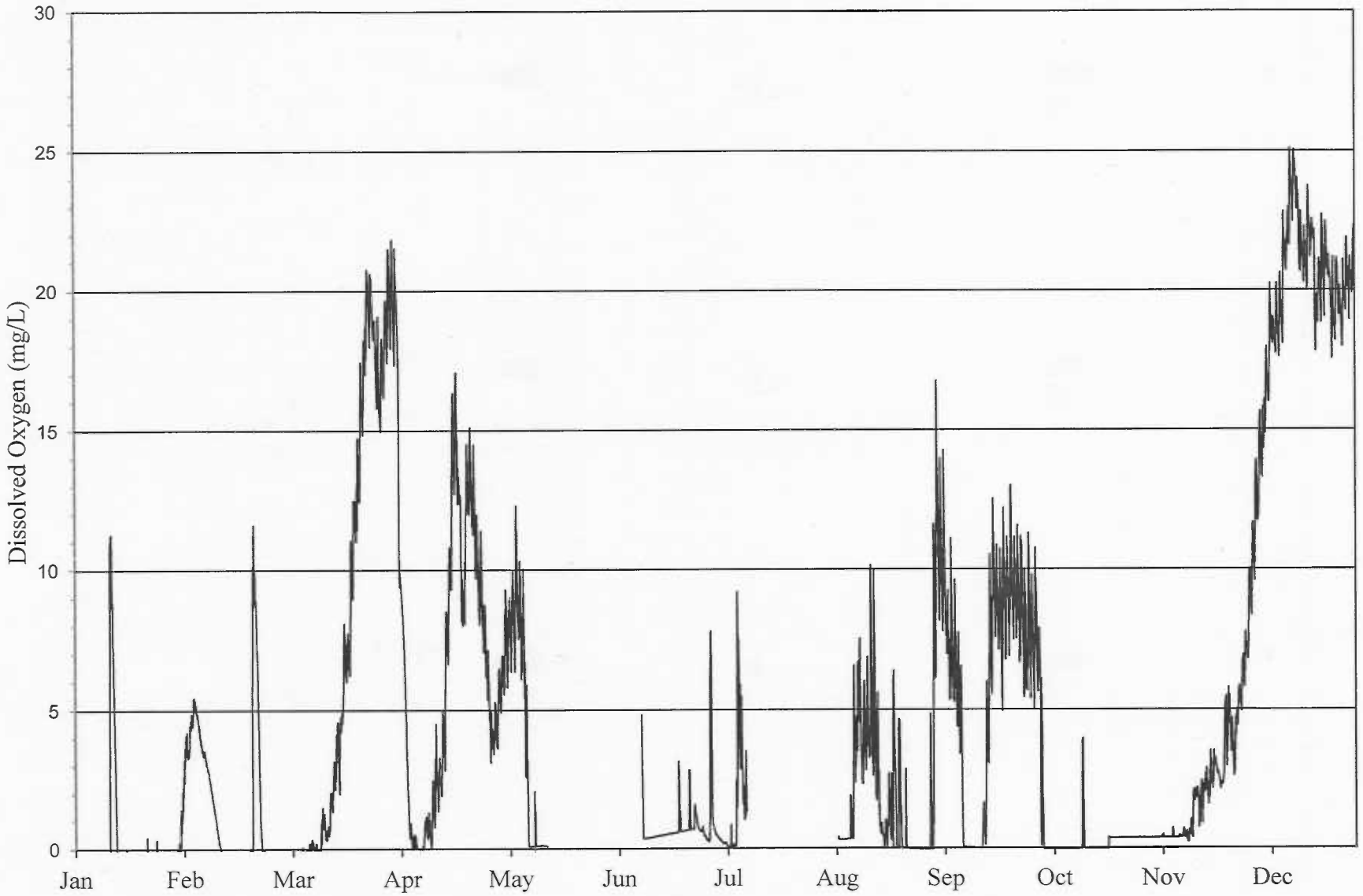


FIGURE 8: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT INTERSTATE HIGHWAY 55 ON BUBBLY CREEK FROM JANUARY 1, 2014 THROUGH DECEMBER 31, 2014

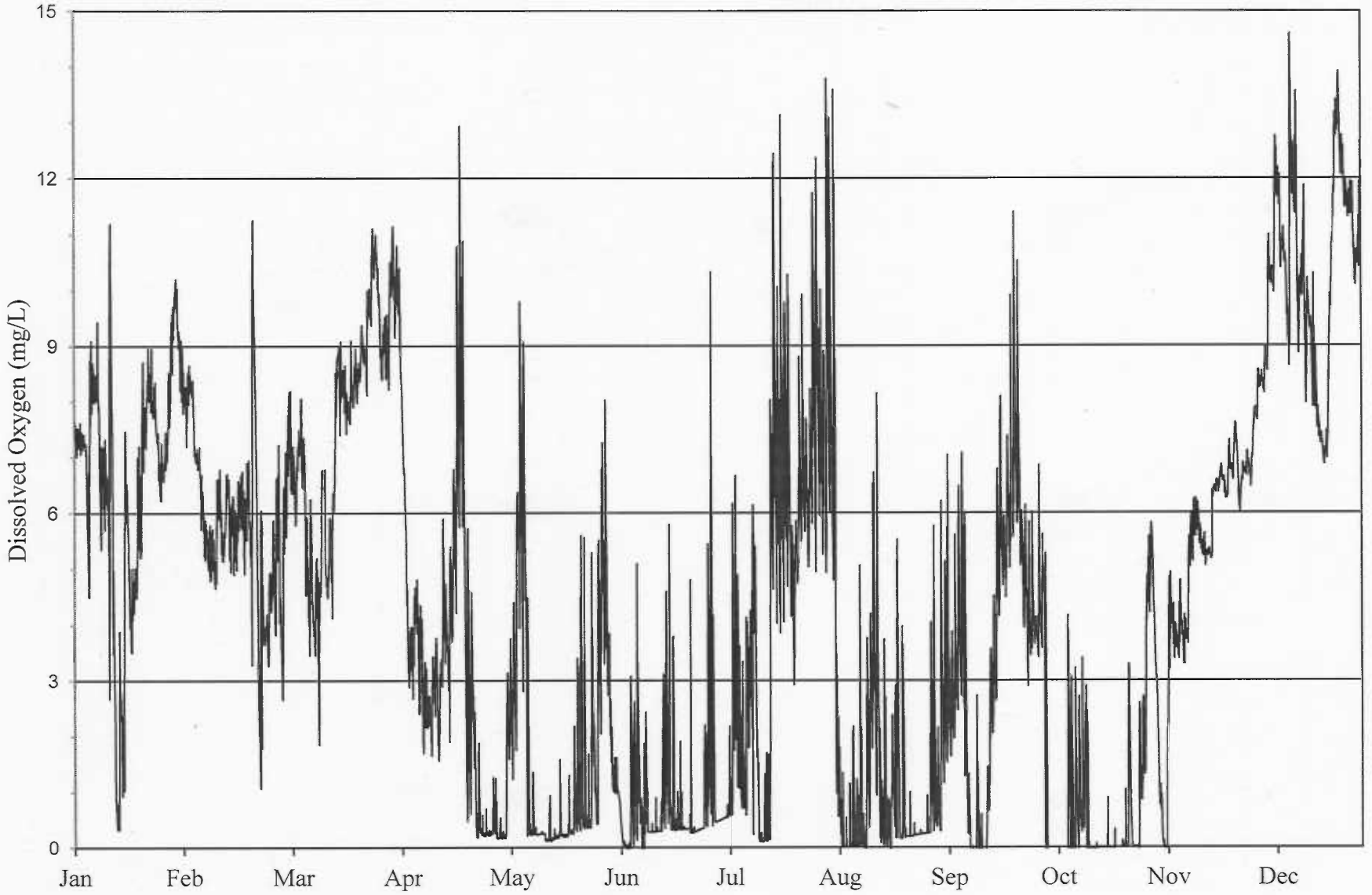


FIGURE 9: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT CICERO AVENUE
ON THE CHICAGO SANITARY AND SHIP CANAL FROM JANUARY 1, 2014 THROUGH DECEMBER 31, 2014

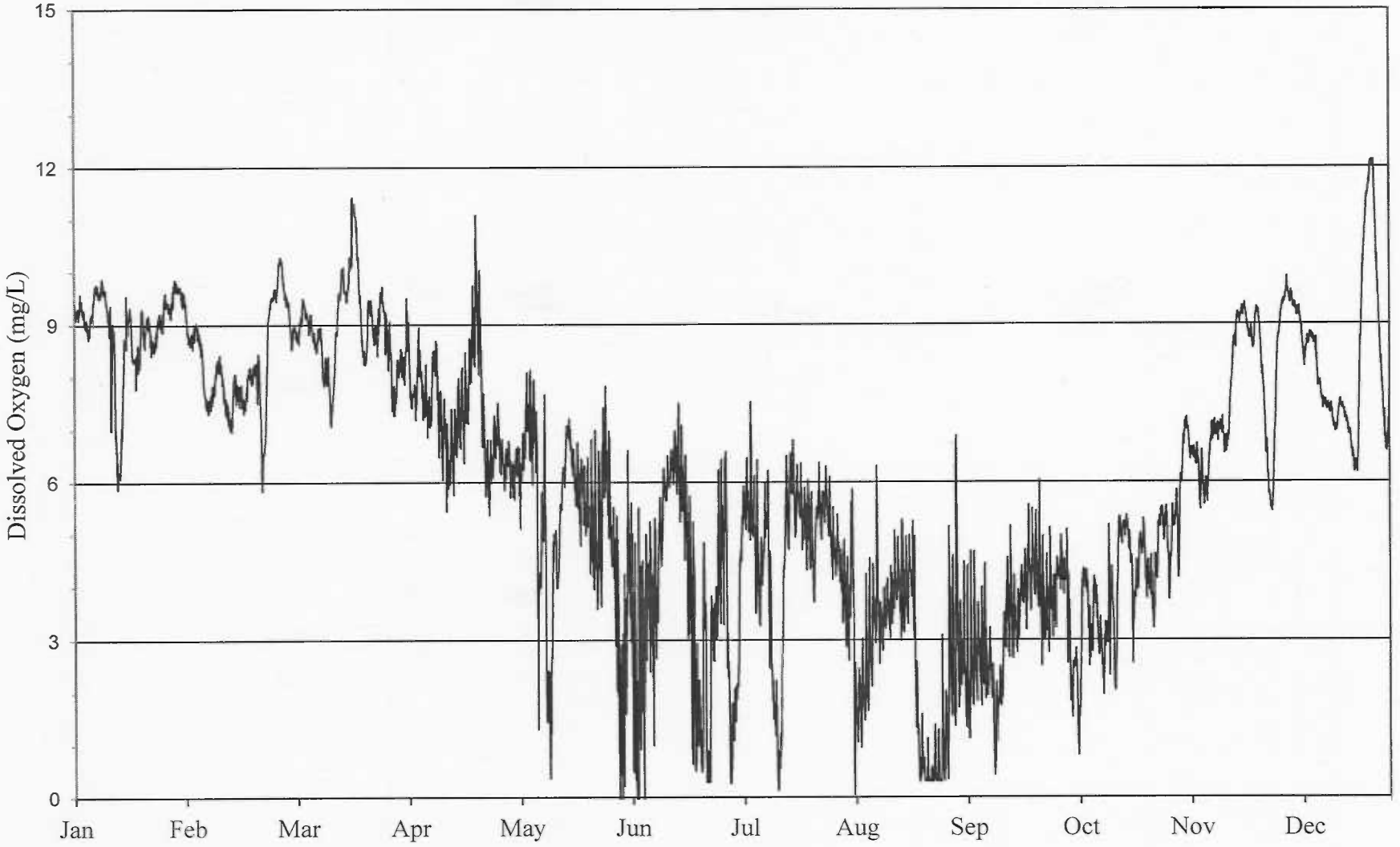


FIGURE 10: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT B&O CENTRAL RAILROAD ON THE CHICAGO SANITARY AND SHIP CANAL, JANUARY 1, 2014 THROUGH DECEMBER 31, 2014

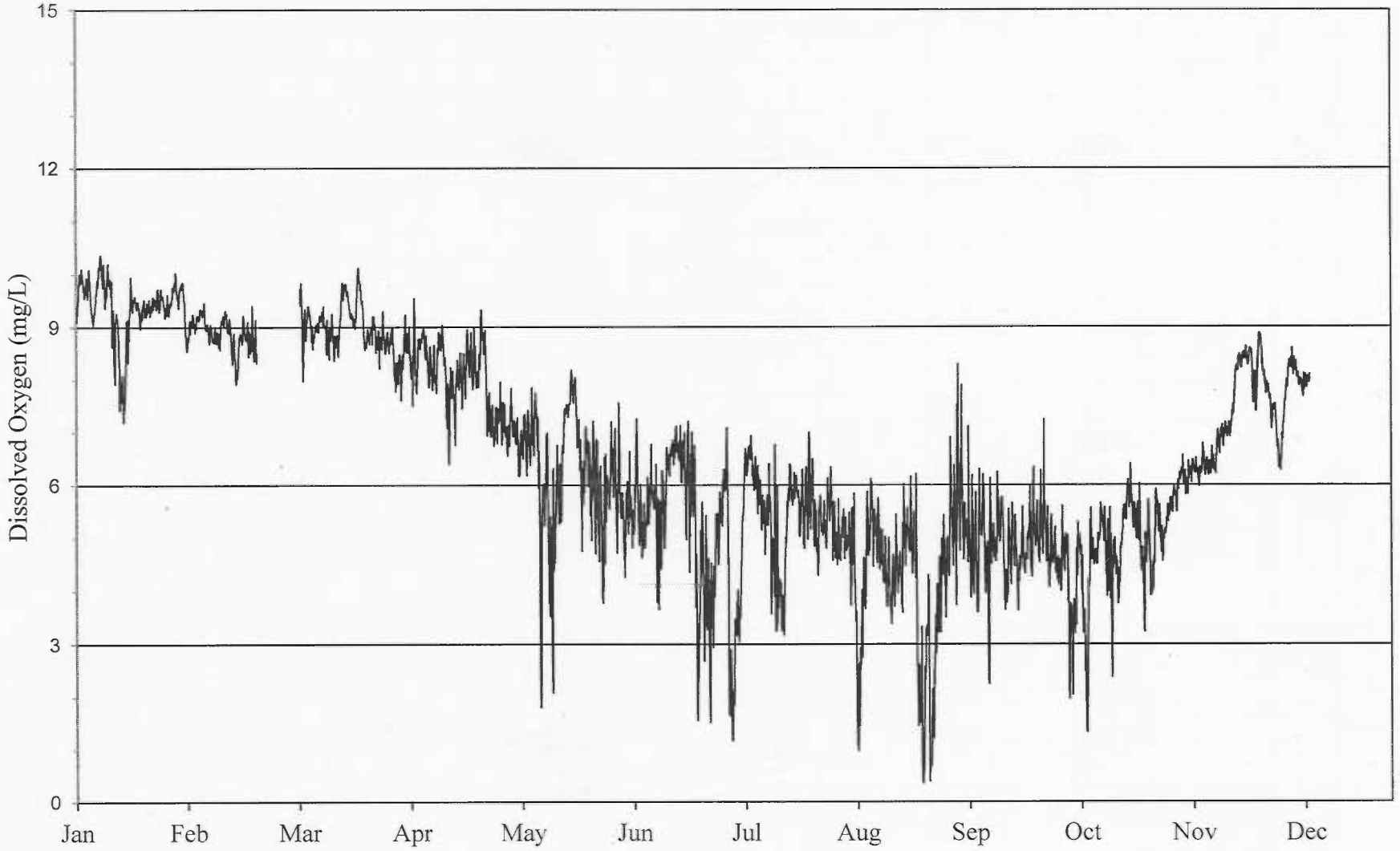


FIGURE 11: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT LOCKPORT POWERHOUSE ON THE CHICAGO SANITARY AND SHIP CANAL, JANUARY 1, 2014 THROUGH DECEMBER 31, 2014

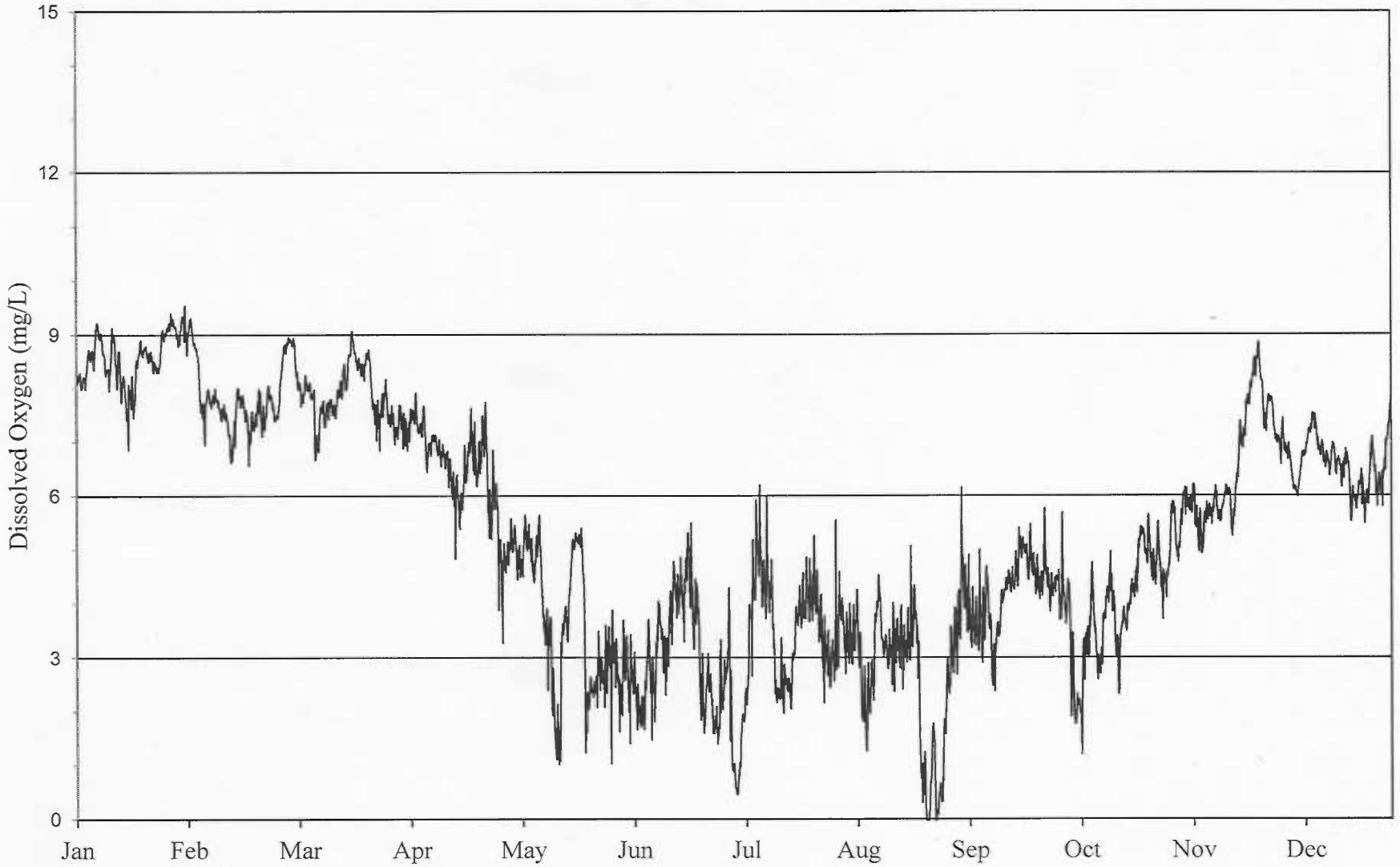


FIGURE 12: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT C&W INDIANA RAILROAD ON THE LITTLE CALUMET RIVER, JANUARY 1, 2014 THROUGH DECEMBER 31, 2014

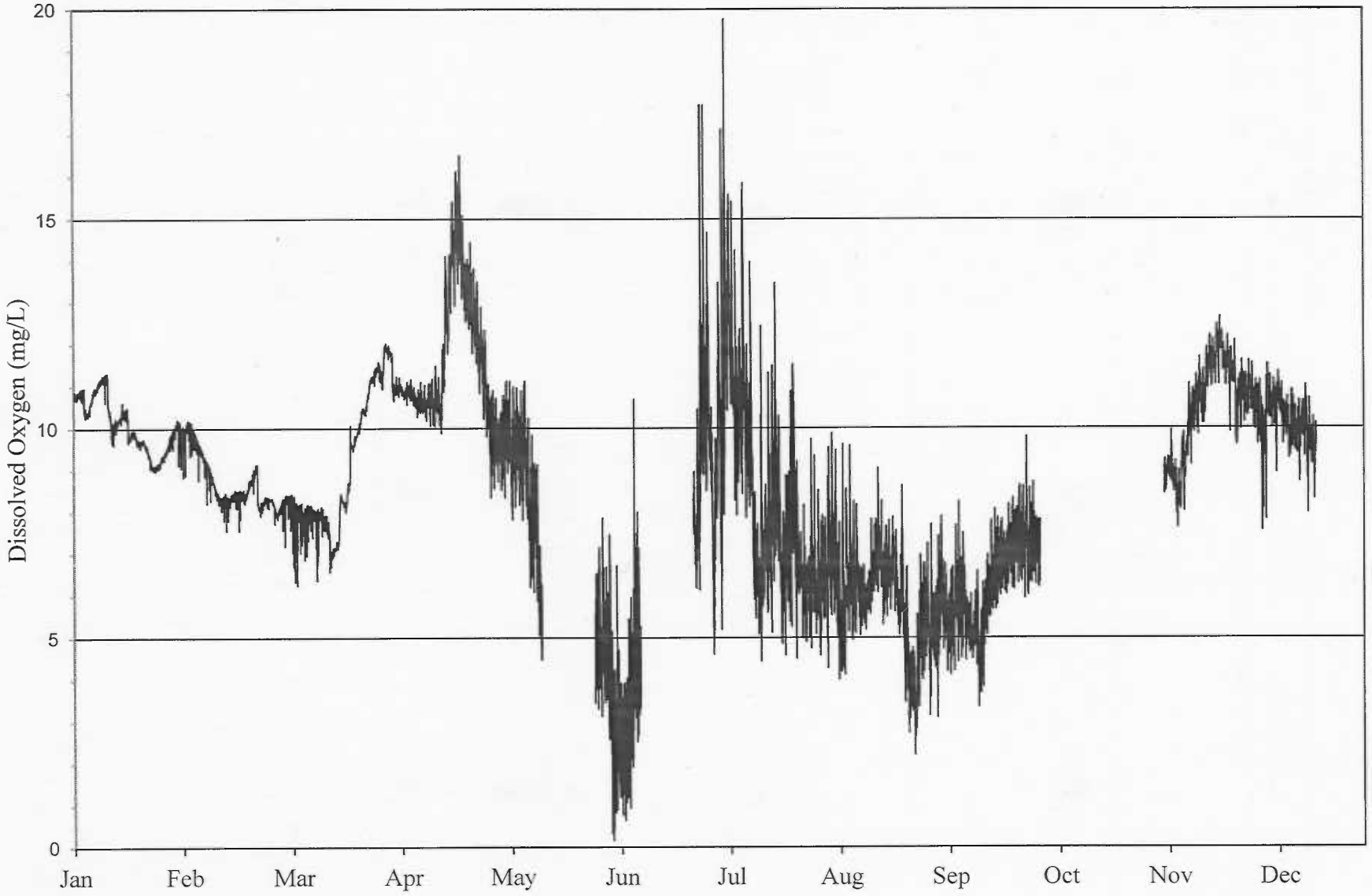


FIGURE 13: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT HALSTED STREET ON THE LITTLE CALUMET RIVER, JANUARY 1, 2014 THROUGH DECEMBER 31, 2014

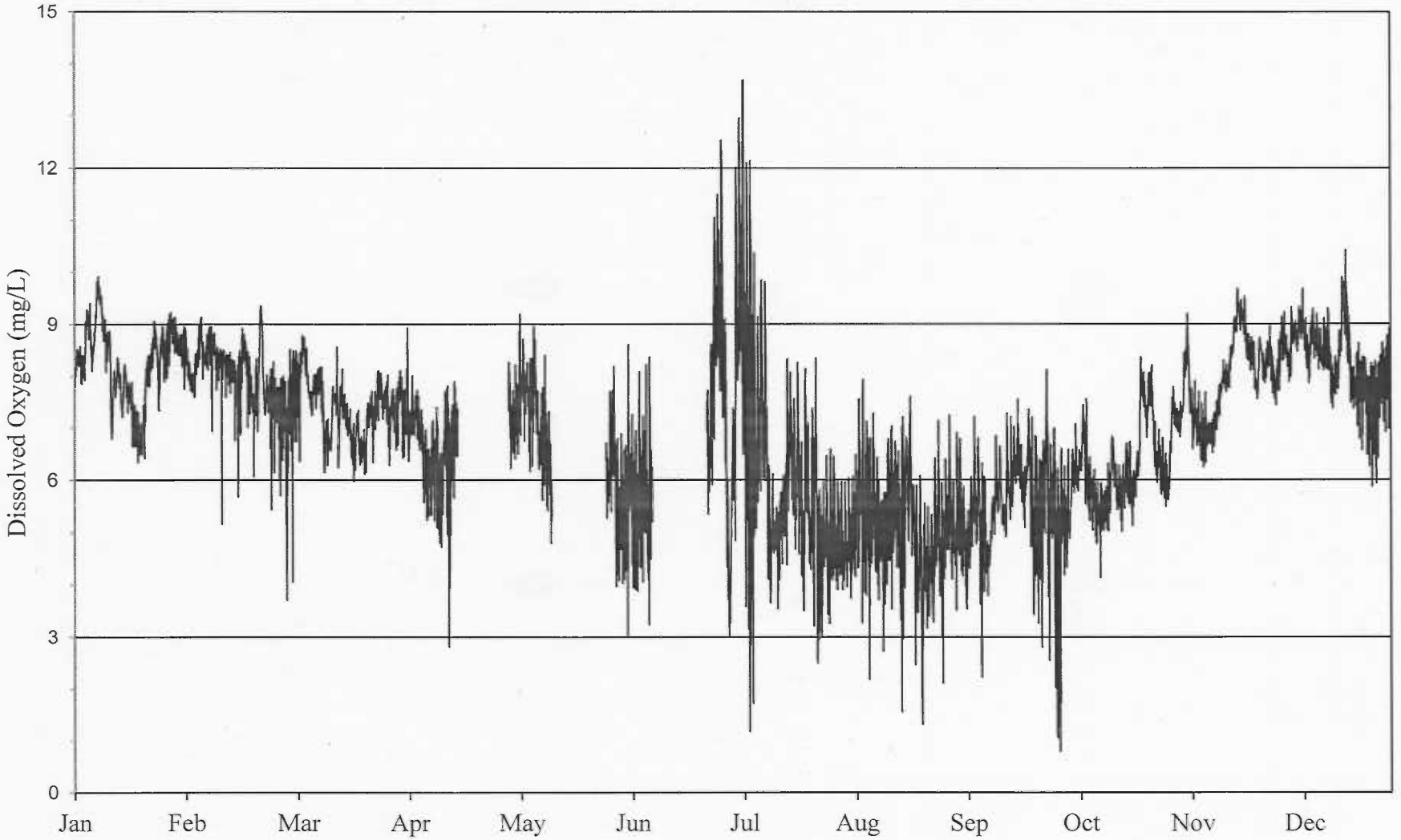


FIGURE 14: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT ASHLAND AVENUE ON THE LITTLE CALUMET RIVER FROM JANUARY 1, 2014 THROUGH DECEMBER 31, 2014

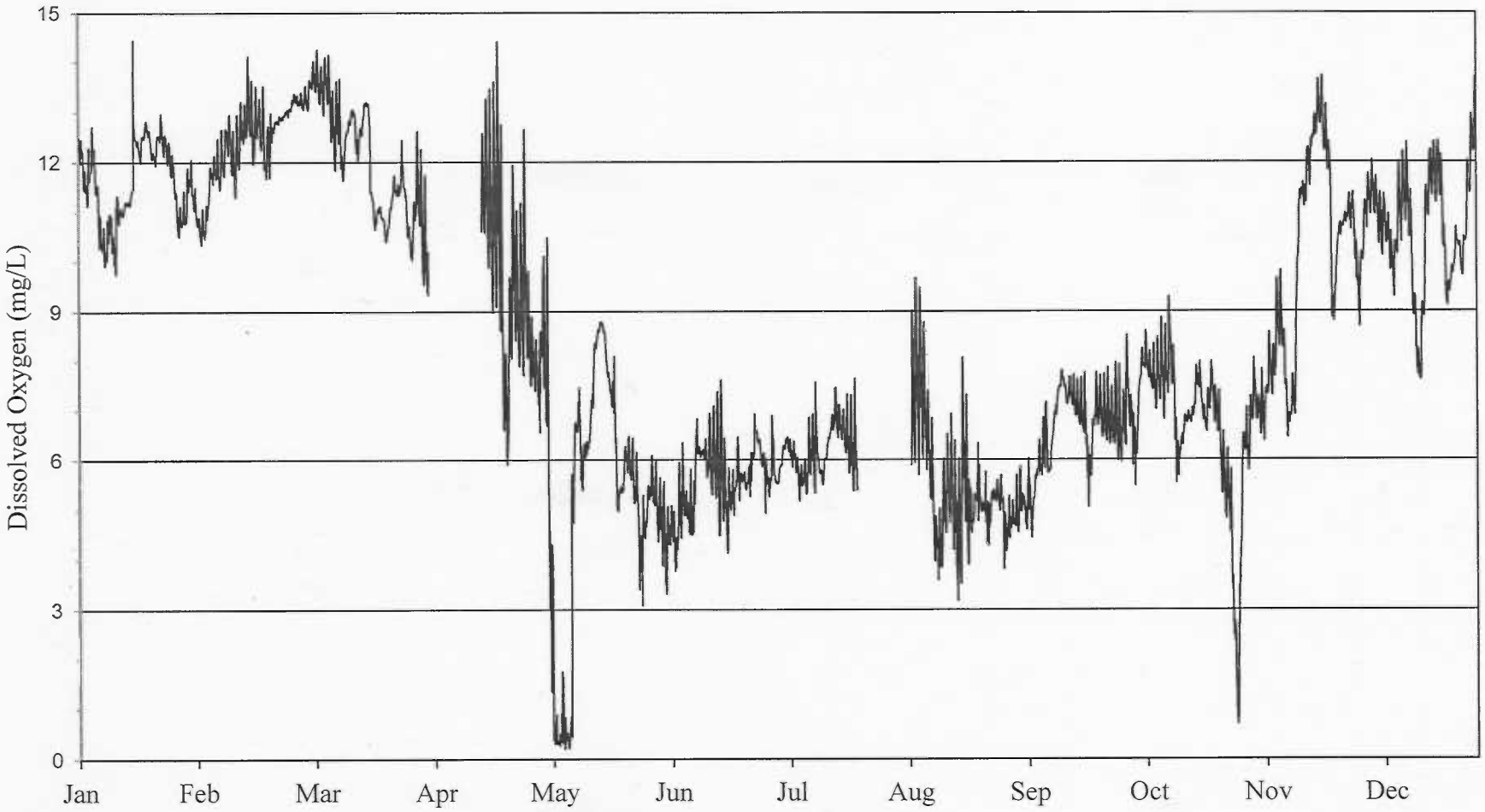


FIGURE 15: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT CICERO AVENUE ON THE CALUMET-SAG CHANNEL FROM MARCH 4, 2014 THROUGH DECEMBER 31, 2014

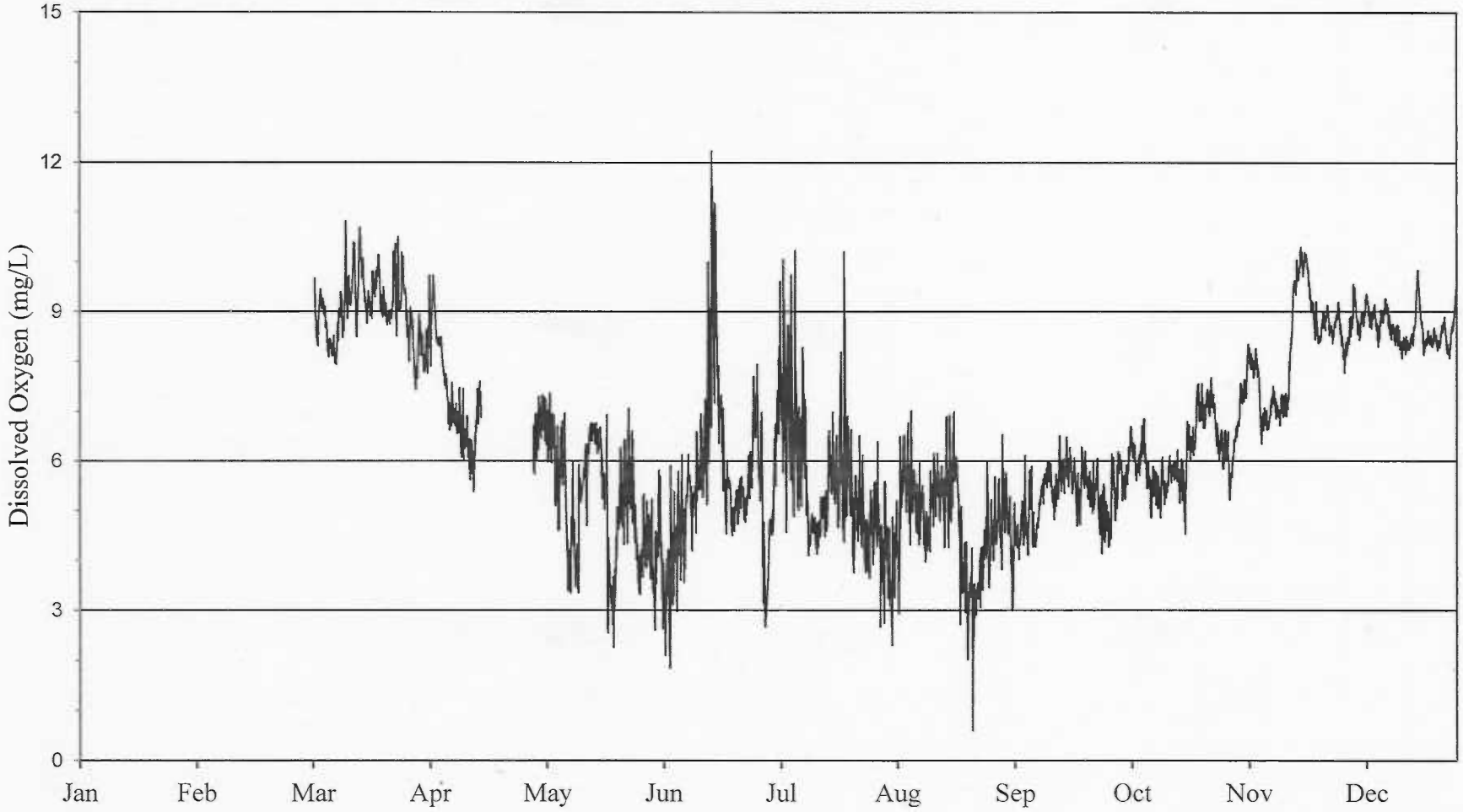


FIGURE 16: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT ROUTE 83
ON THE CALUMET-SAG CHANNEL FROM JANUARY 1, 2014 THROUGH DECEMBER 31, 2014

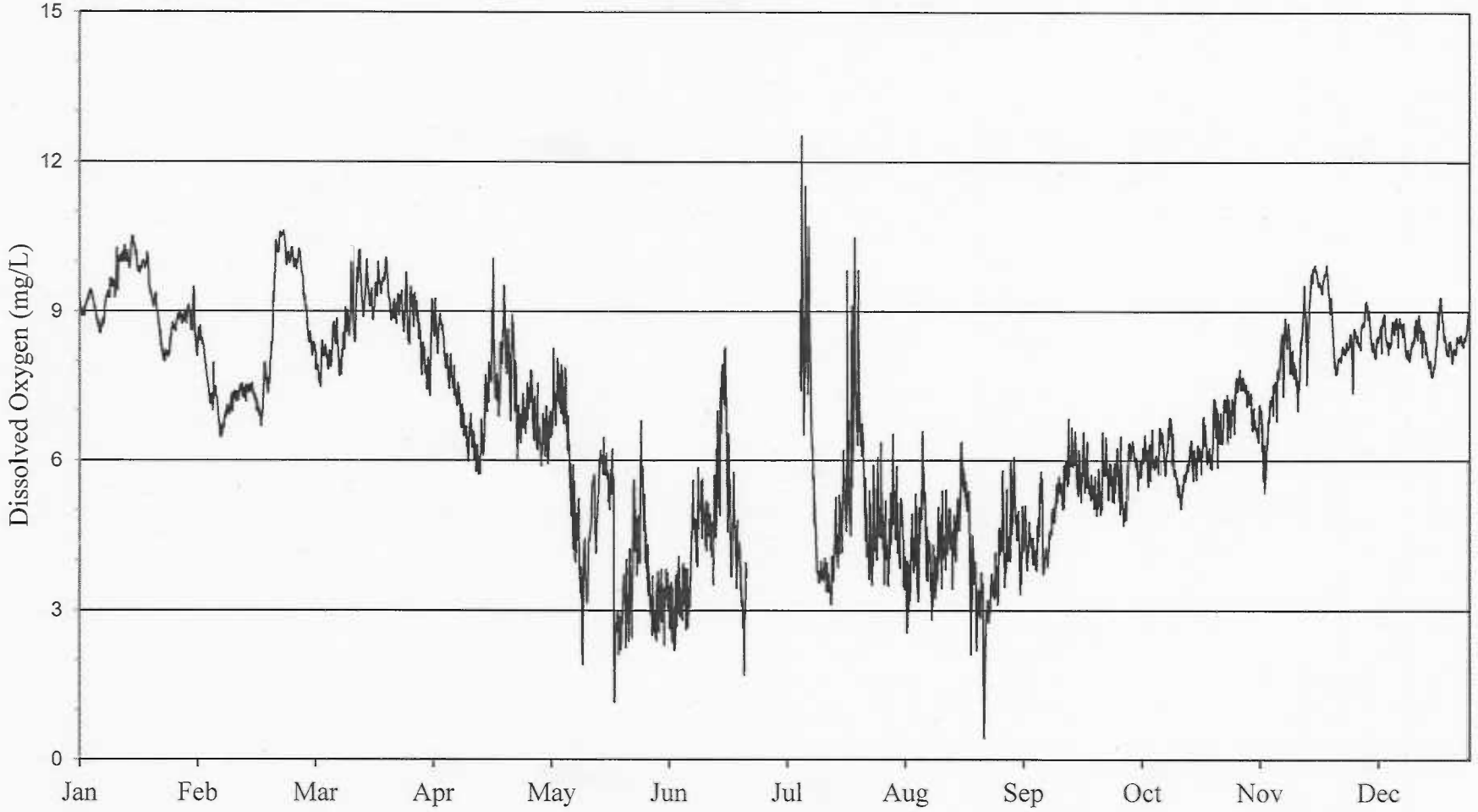


FIGURE 17: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT DEVON AVENUE ON THE DES PLAINES RIVER FROM JANUARY 1, 2014 THROUGH DECEMBER 31, 2014

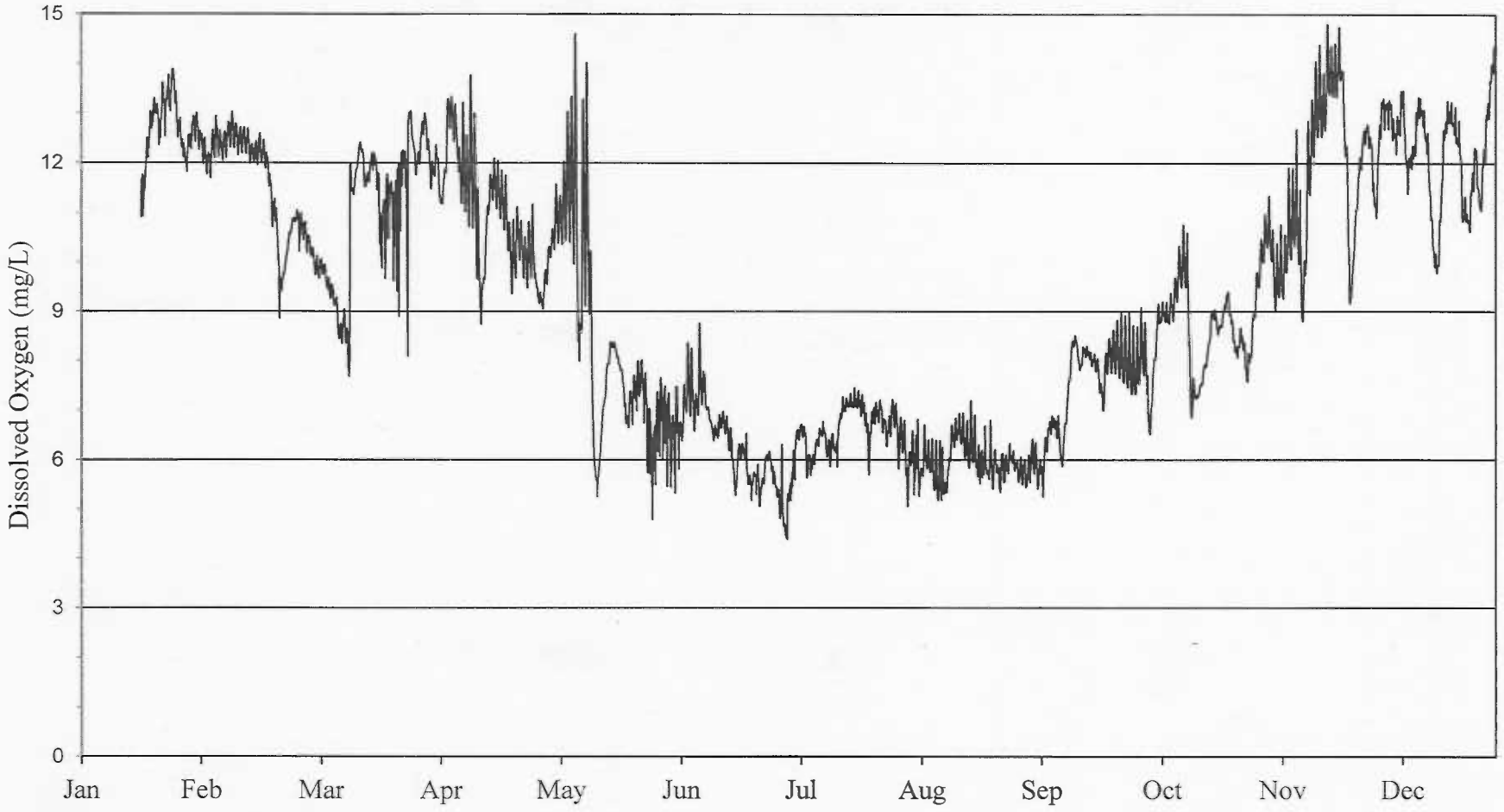


FIGURE 18: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT BUSSE LAKE DAM ON SALT CREEK FROM JANUARY 1, 2014 THROUGH DECEMBER 31, 2014

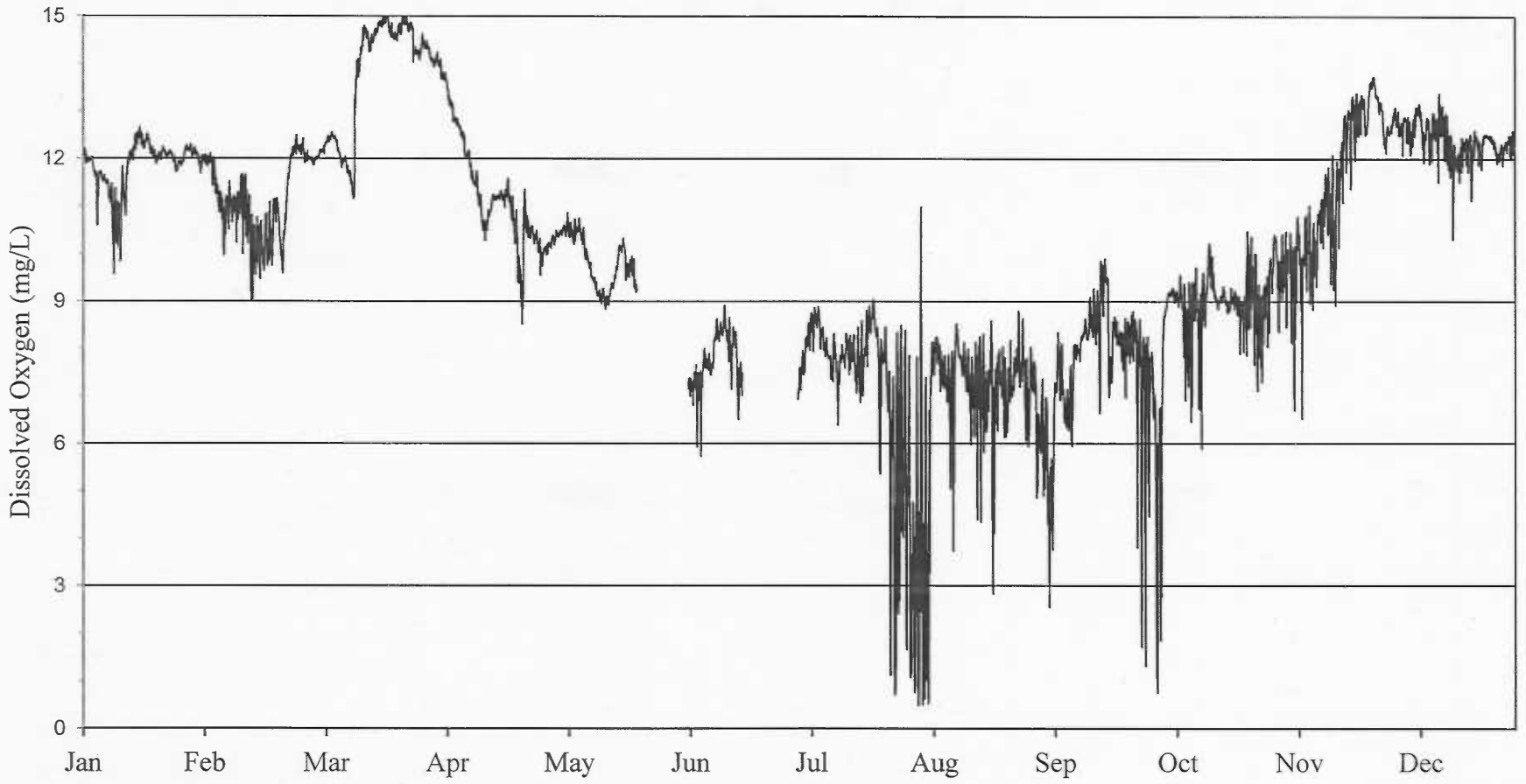


FIGURE 19: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT J.F. KENNEDY BOULEVARD ON SALT CREEK FROM JANUARY 1, 2014 THROUGH DECEMBER 31, 2014

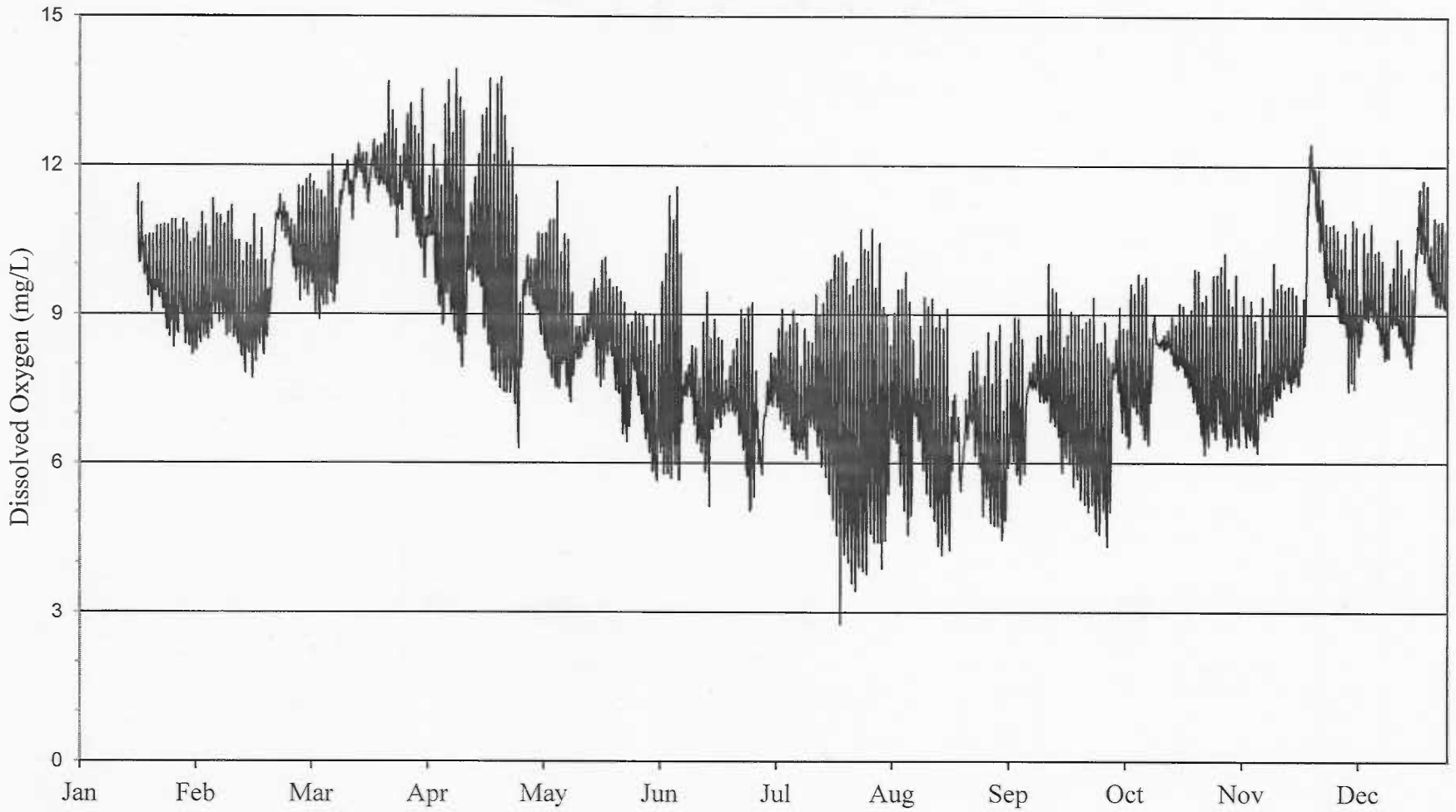
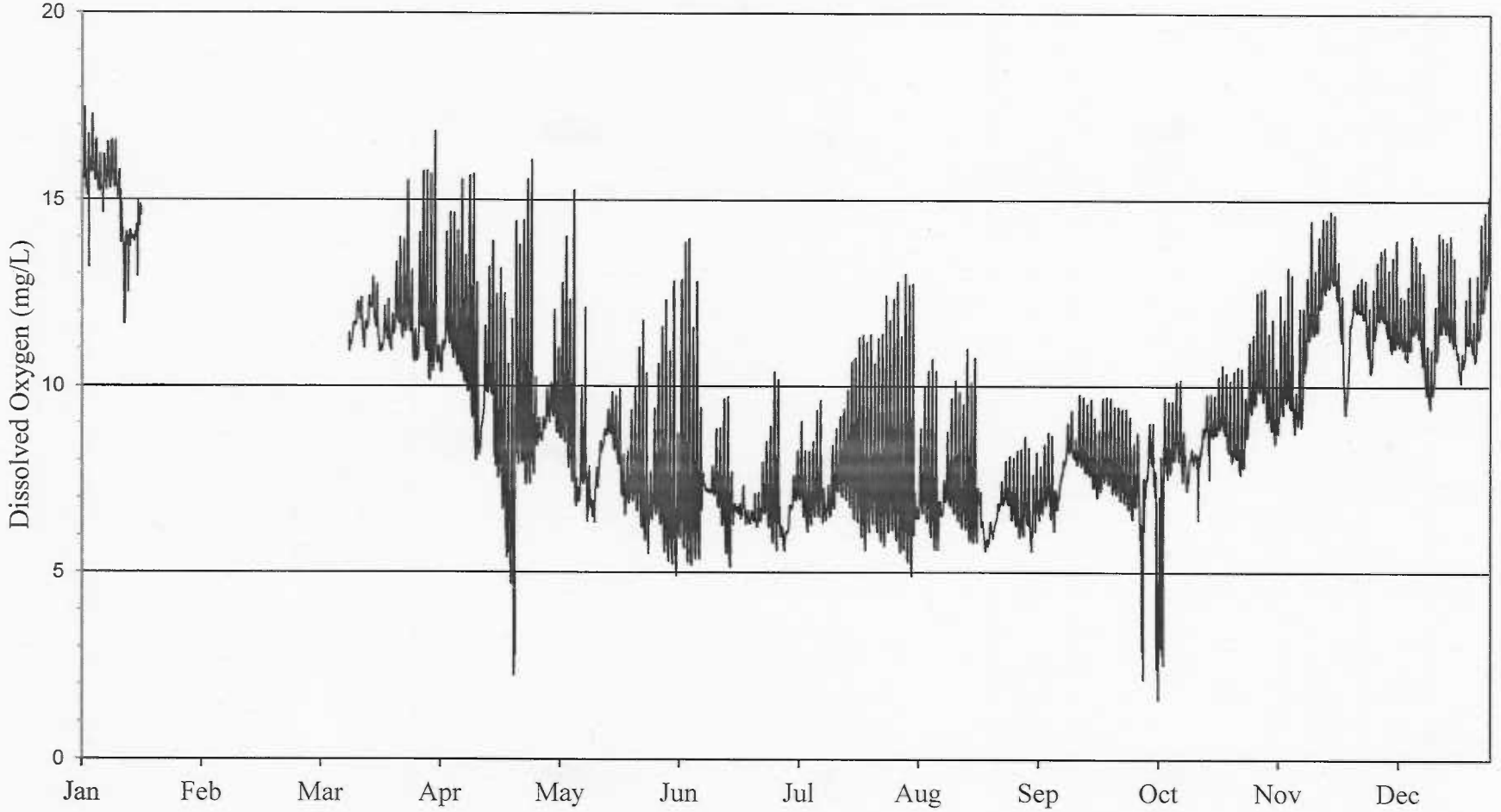


FIGURE 20: DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT WOLF ROAD ON SALT CREEK FROM JANUARY 1, 2014 THROUGH DECEMBER 31, 2014



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 OXGYEN MEASURED DURING CROSS-SECTIONAL SURVEYS IN 2014

TABLE A-1: SUMMARY STATISTICS FOR DISSOLVED OXYGEN MEASURED DURING CROSS-SECTIONAL SURVEYS IN 2014

Waterway, Station, and Date	Water Depth[a] (ft.) Left	Center	Right	N[b]	Minimum (mg/L)	Maximum (mg/L)	Mean (mg/L)	Standard Deviation (mg/L)	Coefficient of Variation (%)
North Shore Channel									
Foster Avenue									
04/29/2014	7.4	9.0	5.7	10	6.36	6.54	6.44	0.06	0.96
08/01/2014	4.0	9.3	3.7	9	7.22	7.30	7.26	0.02	0.34
10/10/2014	3.3	8.9	2.7	8	6.54	6.63	6.57	0.03	0.45
North Branch Chicago River									
Addison Street									
05/22/2014	9.0	8.4	4.7	11	8.00	8.28	8.07	0.08	0.97
08/12/2014	7.8	9.2	4.2	10	6.94	7.03	7.00	0.03	0.47
10/23/2014	7.5	7.3	4.2	12	6.87	6.95	6.91	0.03	0.36
Division Street									
05/22/2014	9.3	15.1	11.4	12	7.35	7.58	7.46	0.08	1.12
08/12/2014	14.7	14.9	9.7	12	6.22	6.32	6.26	0.03	0.44
10/23/2014	12.3	16.3	8.5	12	7.18	7.28	7.24	0.03	0.47
Chicago River									
Clark Street									
05/22/2014	10.1	24.0	19.1	12	6.60	7.66	7.45	0.28	3.73
08/12/2014	14.3	24.1	21.8	12	5.47	6.35	6.11	0.29	4.74
10/23/2014	11.1	22.6	NA	8	8.68	8.72	8.71	0.02	0.17

TABLE A-1 (Continued): SUMMARY STATISTICS FOR DISSOLVED OXYGEN MEASURED DURING CROSS-SECTIONAL SURVEYS IN 2014

Waterway, Station, and Date	Water Depth[a] (ft.) Left	Center	Right	N[b]	Minimum (mg/L)	Maximum (mg/L)	Mean (mg/L)	Standard Deviation (mg/L)	Coefficient of Variation (%)
South Branch Chicago River									
Loomis Street									
04/30/2014	23.4	22.7	17.4	12	7.01	7.23	7.07	0.07	0.92
09/14/2014	19.2	21.8	14.2	12	3.70	3.83	3.75	0.04	1.16
10/15/2014	17.0	22.5	14.2	12	5.17	5.26	5.21	0.03	0.61
Bubbly Creek									
36th Street									
05/13/2014	2.2	3.9	5.3	7	0.21	0.34	0.24	0.04	17.98
09/14/2014	4.2	4.4	1.4	8	8.47	10.48	9.50	0.94	9.90
10/30/2014	2.2	4.6	4.5	8	0.04	3.63	0.82	1.26	154.41
Interstate Highway 55									
05/13/2014	4.8	9.3	8.5	11	0.25	2.67	0.78	0.82	105.28
09/14/2014	4.3	10.7	1.4	8	2.11	2.62	2.43	0.14	5.91
10/30/2014	4.0	11.2	3.4	9	1.29	3.35	1.82	0.66	36.20
Chicago Sanitary and Ship Canal									
Cicero Avenue									
04/30/2014	13.9	19.4	6.8	11	5.93	6.30	6.07	0.12	1.97
09/14/2014	14.0	18.8	10.0	12	2.44	2.82	2.55	0.13	5.18
10/15/2014	11.7	18.3	6.5	11	3.70	4.04	3.87	0.12	2.99

TABLE A-1 (Continued): SUMMARY STATISTICS FOR DISSOLVED OXYGEN MEASURED DURING CROSS-SECTIONAL SURVEYS IN 2014

Waterway, Station, and Date	Water Depth[a] (ft.) Left	Center	Right	N[b]	Minimum (mg/L)	Maximum (mg/L)	Mean (mg/L)	Standard Deviation (mg/L)	Coefficient of Variation (%)
Chicago Sanitary and Ship Canal									
B&O Railroad									
05/01/2014	11.6	21.0	7.2	11	7.01	7.30	7.13	0.09	1.32
08/07/2014	13.3	16.0	5.6	11	3.99	4.28	4.16	0.10	2.44
11/05/2014	11.9	19.6	5.8	11	5.95	6.26	6.04	0.09	1.45
Lockport Powerhouse									
05/30/2014	27.7	29.5	29.5	12	3.32	3.49	3.42	0.05	1.50
07/31/2014	26.4	30.2	30.4	12	3.51	4.13	3.67	0.20	5.32
10/31/2014	22.0	28.3	30.8	12	4.76	5.13	4.85	0.13	2.60
Little Calumet River									
C&W Indiana Railroad									
05/29/2014	8.2	14.1	8.7	12	10.71	11.44	11.06	0.27	2.45
08/07/2014	9.0	14.5	10.5	12	8.04	9.49	8.57	0.54	6.32
11/05/2014	8.9	14.5	8.1	12	9.47	9.58	9.54	0.03	0.34
Halsted Street									
05/01/2014	9.8	13.1	4.3	11	7.72	7.87	7.80	0.06	0.80
08/07/2014	7.4	12.7	5.2	10	7.05	7.81	7.40	0.26	3.45
11/05/2014	8.4	13.9	3.3	10	8.82	9.02	8.91	0.06	0.70

TABLE A-1 (Continued): SUMMARY STATISTICS FOR DISSOLVED OXYGEN MEASURED DURING CROSS-SECTIONAL SURVEYS IN 2014

Waterway, Station, and Date	Water Depth[a] (ft.) Left	Center	Right	N[b]	Minimum (mg/L)	Maximum (mg/L)	Mean (mg/L)	Standard Deviation (mg/L)	Coefficient of Variation (%)
Little Calumet River									
Ashland Avenue									
05/28/2014	2.8	3.5	2.3	6	4.95	5.13	5.04	0.06	1.27
08/04/2014	1.4	2.7	2.4	6	8.41	8.82	8.55	0.14	1.65
10/17/2014	2.4	2.4	3.1	6	7.19	7.21	7.20	0.01	0.10
Calumet-Sag Channel									
Cicero Avenue									
05/01/2014	8.0	12.9	6.1	11	6.51	6.86	6.65	0.11	1.63
08/19/2014	9.3	13.4	9.4	12	5.35	5.86	5.55	0.18	3.21
11/05/2014	8.5	12.9	8.7	12	7.35	7.51	7.43	0.05	0.63
Route 83									
05/01/2014	12.5	13.1	7.7	11	6.88	7.08	6.97	0.07	0.95
08/07/2014	11.5	12.7	8.5	12	4.52	4.91	4.72	0.12	2.50
11/05/2014	14.3	12.7	8.6	12	6.69	6.98	6.81	0.10	1.42
Des Plaines River									
Devon Avenue									
05/02/2014	2.6	4.5	3.5	7	10.19	10.35	10.26	0.06	0.55
08/20/2014	2.1	2.3	1.6	5	5.92	6.34	6.03	0.17	2.87
10/20/2014	2.5	2.1	2.2	6	8.54	8.57	8.55	0.01	0.16

TABLE A-1 (Continued): SUMMARY STATISTICS FOR DISSOLVED OXYGEN MEASURED DURING CROSS-SECTIONAL SURVEYS IN 2014

Waterway, Station, and Date	Water Depth[a] (ft.) Left	Center	Right	N[b]	Minimum (mg/L)	Maximum (mg/L)	Mean (mg/L)	Standard Deviation (mg/L)	Coefficient of Variation (%)
Salt Creek									
Busse Lake Dam									
05/02/2014	1.0	3.6	2.1	5	10.35	10.43	10.39	0.03	0.32
08/20/2014	2.7	3.8	2.7	6	8.01	8.06	8.04	0.02	0.25
10/20/2014	2.2	3.0	3.0	6	9.06	9.29	9.15	0.08	0.89
J.F. Kennedy Boulevard									
05/02/2014	1.1	2.5	2.8	5	9.92	10.24	10.02	0.13	1.26
08/20/2014	1.6	2.6	2.3	5	5.36	6.22	5.61	0.35	6.25
10/20/2014	0.6	1.7	2.2	5	8.27	8.32	8.29	0.02	0.25
Wolf Road									
05/02/2014	3.1	3.4	1.2	6	9.82	9.94	9.89	0.04	0.45
08/08/2014	2.2	1.6	1.4	6	7.73	7.83	7.78	0.03	0.43
10/20/2014	1.4	2.1	1.7	6	9.73	9.80	9.77	0.03	0.29

[a]Water depth at the time of cross sectional survey. Exact measurement location may differ slightly during each event.
[b]Number of DO measurements across transects.