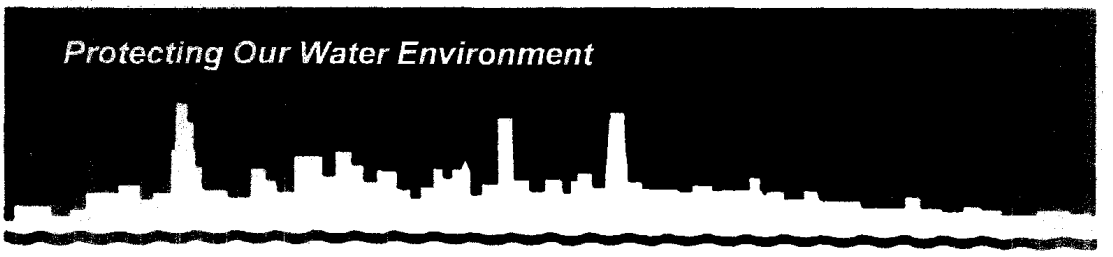

Metropolitan Water Reclamation District of Greater Chicago

RESEARCH AND DEVELOPMENT DEPARTMENT

REPORT NO. 01-5

PRELIMINARY REPORT

DISSOLVED OXYGEN MONITORING

FROM WILMETTE TO LOCKPORT

IN THE CHICAGO WATERWAY SYSTEM

DURING AUGUST 1998 THROUGH JULY 1999

February 2001

Metropolitan Water Reclamation District of Greater Chicago
100 East Erie Street Chicago, IL 60611-2803 (312) 751-5600

PRELIMINARY REPORT

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By

Irwin Polls
Microbiologist IV

Bernard Sawyer
Coordinator of Research

Prakasam Tata
Assistant Director of Research and Development
Environmental Monitoring and Research Division

Research and Development Department
Richard Lanyon, Director

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Particular thanks are due to Ms. Olga Mackey for typing the summary report.

DISCLAIMER

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

SUMMARY AND CONCLUSIONS

Summary

More than 30 years ago, the Metropolitan Water Reclamation District of Greater Chicago (District) determined that applicable dissolved oxygen (DO) standards for deep draft navigable waterways in the Chicago area could not be maintained exclusively by improving discharges from District Water Reclamation Plants (WRPs) and capturing and treating combined sewer overflows. Subsequently, the District constructed and operated two diffused instream aeration stations and five sidestream elevated pool aeration stations in Chicago area waterways in order to provide supplemental aeration.

In August 1996, the District began planning a comprehensive study of existing DO levels in order to locate and identify reaches in the Chicago Waterway System where the DO concentration is less than the applicable Illinois Pollution Control Board (IPCB) water quality standards (3.0 to 5.0 mg/L depending upon the waterway).

Initially, 20 stations were selected for remote monitoring from Wilmette, Illinois on the North Shore Channel to the Lockport Powerhouse and Lock on the Chicago Sanitary and Ship Canal. Additional stations were installed in the Chicago River in 2000 and are being installed in 2001 in the Calumet River, Little Calumet River, and Cal-Sag Channel in order to provide for monitoring of the entire Chicago Waterway System.

In the present study, DO was measured hourly at 20 stations for a two-year period (August 1998 through July 2000) using continuous water quality monitors, Models 6600 and 6920 manufactured by Yellow Springs, Incorporated, (YSI), Yellow Springs, Ohio.

This report is preliminary and includes DO data collected during the first year of monitoring (August 1998 through July 1999). A later report will be prepared that will include DO data from the second year of monitoring (August 1999 through July 2000) and discuss the impact of the operation of the in-stream aeration stations, discretionary diversion from Lake Michigan, and combined sewer overflows on DO levels in the waterways.

Conclusions

The results of the DO monitoring conducted in the Chicago Waterway System during the period from August 1998 through July 1999 indicate the following.

1. DO supersaturation occurred occasionally at Main Street in the North Shore Channel and Interstate 55 in the South Fork of the South Branch of the Chicago River. Hourly DO concentrations of 0 mg/L were recorded numerous times at Linden Street, Simpson Street, and Main Street in the North Shore Channel and Interstate 55 in the

South Fork of the South Branch of the Chicago River.

2. None of the 20 monitoring stations recorded DO concentrations above the applicable IPCB standards at all times. However, four monitoring stations were above the applicable IPCB DO standard over 99 percent of the time. The four were Devon Avenue in the North Shore Channel, Lawrence Avenue and Addison Street in the North Branch of the Chicago River, and Clark Street in the Chicago River.

3. Monitoring stations where the DO concentration was above the DO standard 90 to 99 percent of the time included Fullerton Avenue, Division Street, and Kinzie Street in the North Branch of the Chicago River, Jackson Boulevard and Loomis Street in the South Branch of the Chicago River, B&O Central Railroad and River Mile 302.6 in the Chicago Sanitary and Ship Canal, and Route 83 in the Cal-Sag Channel.

4. Monitoring stations recording DO concentrations above the DO standards 50 to 90 percent of the time included Main Street in the North Shore Channel, Interstate 55 in the South Fork of the South Branch of the Chicago River, Cicero Ave-

nue, Route 83, Romeoville Road, and Lockport in the Chicago Sanitary and Ship Canal.

5. The DO concentration at Linden Street and Simpson Street in the North Shore Channel was above the DO standard less than 50 percent of the time.

The data resulting from the operation of the continuous DO monitors has been found to be an important source of information for determining the oxygen levels in a complex, urban waterway system. This information will be useful in future studies, such as determining the need and location for additional supplemental aeration capacity, understanding the temporal and transient impacts of combined sewer overflows, assessing the effects of reduced discretionary diversion from Lake Michigan, and calibration and verification of an unsteady-state water quality model for the Chicago Waterway System.

INTRODUCTION

Over the years, increased pollutant loading from urbanization throughout the Chicago metropolitan area and low velocities in Chicago area deep draft waterways have caused DO concentrations to fall below DO standards established by the IPCB.

More than 30 years ago, the District determined that applicable IPCB DO standards for area waterways could not be met exclusively by advanced wastewater treatment at its WRPs and the capture and treatment of combined sewer overflows. In order to increase the DO concentration in the Chicago and Calumet River Systems, the District designed and constructed artificial aeration systems (instream diffuser and sidestream elevated pool aeration) during the late 1970s and early 1990s, respectively.

From October 1994 through May 1996, the Research and Development (R&D) Department conducted weekly DO surveys in the Chicago Waterway System. Water samples were collected manually, fixed in the field, and returned to the laboratory for titration. The results from these surveys showed that DO values in specified waterway reaches were less than IPCB DO standards applicable to these reaches.

In August 1996, it was determined that the R&D Department develop and conduct a comprehensive field-monitoring program in order to locate and identify reaches in the Chicago Water-

way System where the DO concentration is less than the applicable IPCB DO standard. Initially, the program was to focus on the Chicago River System and the Chicago Sanitary and Ship Canal for a two-year period. Subsequently, the scope of the monitoring program was extended to four years, and the study area was expanded to include the Calumet River System and the Cal-Sag Channel for the latter two years.

This report summarizes the results from the first year of monitoring (August 1998 through July 1999). A later report will include data collected during the second year of monitoring (August 1999 through July 2000) and discuss the impact of the operation of instream aeration stations, discretionary diversion from Lake Michigan, and combined sewer overflows on DO levels in the Chicago Waterway System to determine if additional supplemental aeration is needed to comply with IPCB DO standards. In addition, the DO data generated in the present study will be useful for calibrating and verifying a water quality model that is currently being developed for unsteady-state flow conditions in the Chicago Waterway System.

MONITORING STATIONS

Twenty stations were selected for DO monitoring along the Chicago Waterway System from Wilmette, Illinois on the North Shore Channel to the Lockport Lock on the Chicago Sanitary and Ship Canal (Figure 1).

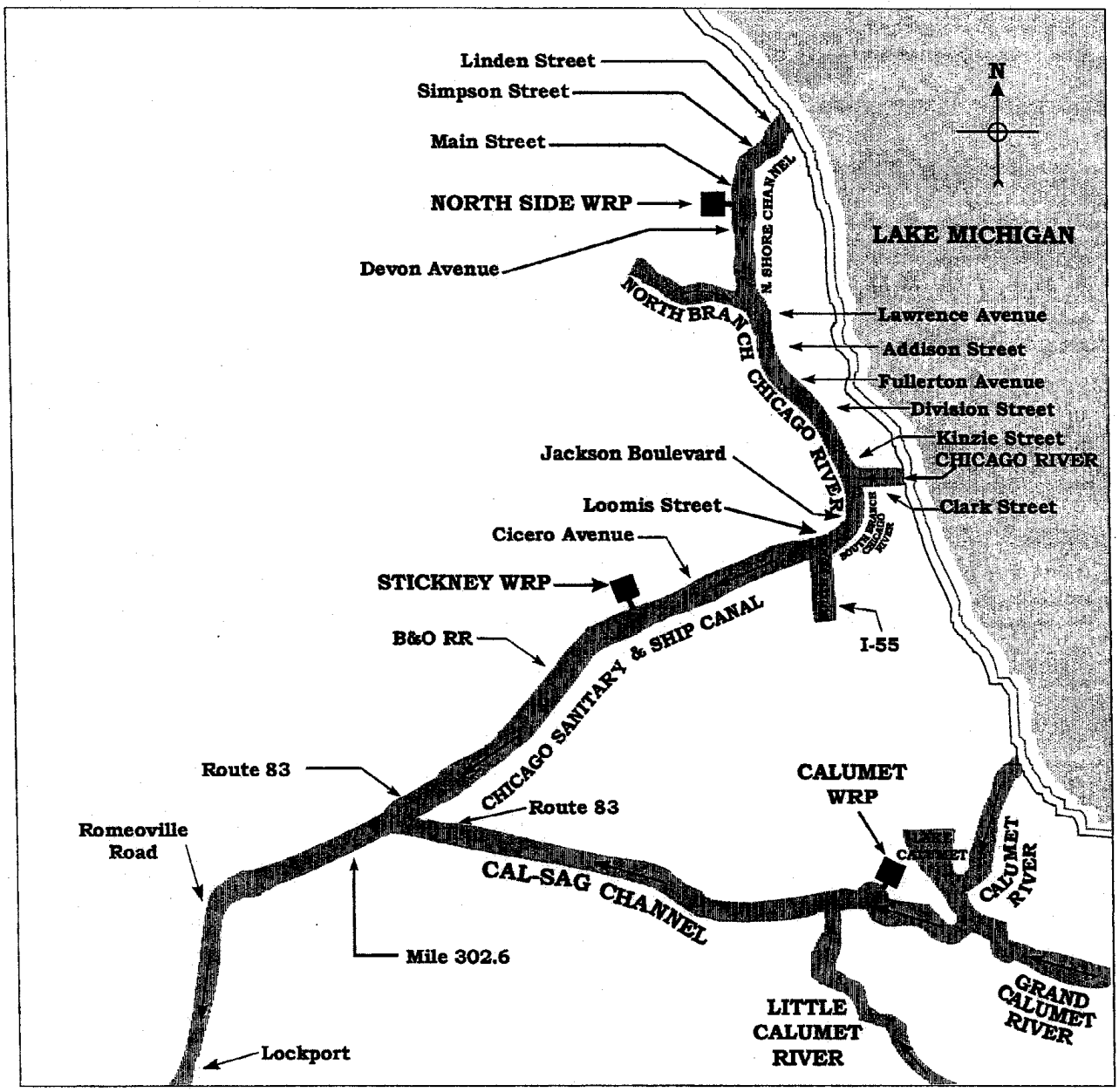
Criteria used to select monitoring stations included the following: (1) history of low DO; (2) above and below confluence of waterways; (3) proximity to instream aeration stations and wastewater pumping stations; and (4) above and below the North Side and Stickney WRPs.

Four stations were located on the North Shore Channel, 5 on the North Branch of the Chicago River, 1 on the Chicago River, 2 on the South Branch of the Chicago River, 1 on the South Fork of the South Branch of the Chicago River, 6 on the Chicago Sanitary and Ship Canal, and 1 station on the Cal-Sag Channel. Table 1 describes the locations of the 20 monitoring stations.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 1

LOCATION OF REMOTE DISSOLVED OXYGEN MONITORING STATIONS



METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 1

CONTINUOUS DISSOLVED OXYGEN MONITORING LOCATIONS

Monitoring Location	Waterways	Description of Monitoring Location
Linden Street	North Shore Channel	0.1 mile below Wilmette Pumping Station; 7.1 miles above North Side WRP outfall; water quality monitor under Linden Street bridge, center of channel, one foot above bottom.
Simpson Street	North Shore Channel	1.6 miles below Wilmette Pumping Station; 5.6 miles above North Side WRP outfall; water quality monitor under Simpson Street bridge, center of channel, one foot above bottom.
Main Street	North Shore Channel	4.1 miles below Wilmette Pumping Station; 3.1 miles above North Side WRP outfall; water quality monitor under Main Street bridge, center of channel, one foot above bottom.
Devon Avenue	North Shore Channel	1.2 miles below North Side WRP outfall; 0.1 mile above Devon Aeration Station; water quality monitor under Devon Avenue bridge, center of channel, one foot above bottom.
Lawrence Avenue	North Branch Chicago River	3.5 miles below North Side WRP outfall; 0.4 miles below junction with North Shore Channel; 0.1 mile below Lawrence Avenue Pumping Station; water quality monitor on northwest side Lawrence Avenue bridge, three feet below water surface.
Addison Street	North Branch Chicago River	5.2 miles below North Side WRP outfall; water quality monitor on northwest side Addison Street bridge, three feet below water surface.
Fullerton Avenue	North Branch Chicago River	7.4 miles below North Side WRP outfall; 0.4 miles above Webster Aeration Station; water quality monitor on northwest side Fullerton Avenue bridge, three feet below water surface.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 1 (Continued)

CONTINUOUS DISSOLVED OXYGEN MONITORING LOCATIONS

Monitoring Location	Waterways	Description of Monitoring Location
Division Street	North Branch Chicago River	8.8 miles below North Side WRP outfall; 1.4 miles below Webster Aeration Station; water quality monitor on northeast side Division Street bridge, three feet below water surface.
Kinzie Street	North Branch Chicago River	9.9 miles below North Side WRP outfall; 0.1 mile above junction with Chicago River; water quality monitor on northeast side Kinzie Street bridge, three feet below water surface.
Clark Street	Chicago River	1.2 miles below Chicago River Controlling Works; 0.4 miles above junction with South Branch Chicago River; water quality monitor on southeast side Clark Street bridge, three feet below water surface.
Jackson Boulevard	South Branch Chicago River	1.0 mile below junction with Chicago River; water quality monitor on northeast side of Jackson Boulevard bridge, three feet below water surface.
Loomis Street	South Branch Chicago River	4.0 miles below junction with Chicago River; 0.4 miles below Fisk Generating Station discharge; water quality monitor on northeast side Loomis Street bridge, three feet below water surface.
Interstate 55	South Fork of the South Branch Chicago River	1.0 mile below Racine Avenue Pumping Station; 0.4 miles above junction with South Branch Chicago River; water quality monitor on northeast side I-55 bridge, three feet below water surface.
Cicero Avenue	Chicago Sanitary & Ship Canal	1.9 miles above Stickney WRP outfall; 1.0 mile below Crawford Generating Station cooling water discharge; water quality monitor on northeast side Cicero Avenue bridge, three feet below water surface.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 1 (Continued)

CONTINUOUS DISSOLVED OXYGEN MONITORING LOCATIONS

Monitoring Location	Waterways	Description of Monitoring Location
B&O Central RR	Chicago Sanitary & Ship Canal	6.8 miles below Stickney WRP outfall; water quality monitor in center of canal, east side B&O RR bridge, three feet below water surface.
Route 83	Chicago Sanitary & Ship Canal	1.0 mile above junction with Cal-Sag Channel; 0.8 miles above Canal Junction SEPA Station; water quality monitor 0.3 miles above Route 83 bridge, center of canal, one foot above bottom.
Mile 302.6	Chicago Sanitary & Ship Canal	1.2 miles below junction with Cal-Sag Channel; 1.3 miles below Canal Junction SEPA Station; water quality monitor in center of canal, one foot above bottom.
Romeoville Road	Chicago Sanitary & Ship Canal	7.1 miles below junction with Cal-Sag Channel; 5.1 miles above Lockport Lock; water quality monitor on southeast side Romeoville Road bridge, three feet below water surface.
Lockport	Chicago Sanitary & Ship Canal	0.1 mile above Lockport Powerhouse; 1.1 miles above junction with Des Plaines River; water quality monitor on north side of canal, in forebay area on fender wall, three feet below water surface.
Route 83	Cal-Sag Channel	0.3 miles above junction with Chicago Sanitary & Ship Canal; 0.2 miles above Canal Junction SEPA Station; water quality monitor on southwest side Gulf, Mobile & Ohio RR bridge, three feet below water surface.

MATERIALS AND METHODS

Water Quality Monitor

Monitoring at the 20 stations was initiated in August 1998 and continued through July 1999. Monitoring will continue, and additional data will be reported in future reports. In the present study, DO was measured hourly using the YSI Model 6920 continuous water quality monitor (monitor).

In order to protect and safeguard the monitors from marine navigation and vandalism, the monitors were deployed in the field in stainless steel pipes. Two different installation designs were employed: (1) a 3-foot stainless steel pipe was suspended 1 foot off the bottom of the waterway and orientated downstream such that the water passed through the pipe, and (2) a 12- to 15-foot pipe with multiple 2-inch circular openings was vertically mounted on the side of a bridge abutment.

Servicing the monitors followed a weekly schedule. Industrial Waste Division (IWD) personnel retrieved each monitor from the field following seven days of continuous monitoring. Prior to retrieval, a grab sample was collected in the waterway for DO analysis. An additional monitor that had been previously calibrated and serviced in the laboratory was then deployed to replace the monitor retrieved. 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 large holding tanks containing tap water for subsequent deployment the following week.

Data Management and Review

Hourly DO data was directly exported electronically from individual monitors to a specially designed Access® database for data processing and storage. Following data downloading, the weekly DO data was carefully reviewed for accuracy. The review process included the following: (1) Comparing a grab sample DO value measured in the field and a DO value recorded by a retrieved monitor (DO rejection criteria = difference greater than 2.0 mg/L); (2) Comparing the last hourly DO value measured by a retrieved monitor and the first hourly DO value recorded by a deployed monitor (DO rejection criteria = difference greater than 2.0 mg/L); and (3) Comparing a DO value measured in a laboratory holding tank and a DO value recorded by a retrieved monitor (DO rejection criteria = difference greater than 1.0 mg/L).

After careful review of the DO data, weekly summary statistics (mean, minimum, maximum, and percent observations above DO standard) and line drawings were prepared.

Verification of Representative Data

Cross-sectional DO surveys were conducted during the fall of 1998 and the spring and summer of 1999 to determine if a fixed monitoring location accurately represented the DO con-

centration across the waterway. Verification was achieved by comparing the DO concentration measured in grab samples collected at multiple fixed locations and depths across the waterway with the fixed monitor measurements, as described above. The results from the cross-sectional surveys clearly showed that the differences across the waterway were minimal and equivalent to the DO values measured by the monitors at the fixed locations.

RESULTS AND DISCUSSION

The number and percent of DO values rejected and removed from the Access® database are summarized in Table 2. Based on the data review methodology previously described, 9 percent of the DO data was rejected. The number of DO values rejected ranged from a low of 19 (0.2 percent) at Kinzie Street in the North Branch of the Chicago River to a high of 2,157 (24.7 percent) at Route 83 in the Chicago Sanitary and Ship Canal.

The minimum, maximum, and mean DO concentrations measured at the 20 stations from August 1998 through July 1999 are shown in Table 3. The number and percent of DO values above the applicable IPCB DO standard for the subject waterways are presented in Table 4. The DO data shown in Table 4 does not include DO values rejected during data review.

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 Waterway System, General Use Waters include the North Shore Channel from Lake Michigan to the North Side WRP, the Chicago River, and the Calumet River.

Secondary Contact Waters include the North Shore Channel from the North Side WRP to the North Branch of the Chicago River, the North Branch of the Chicago River from the North

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 2

NUMBER AND PERCENT OF DISSOLVED OXYGEN VALUES REJECTED DURING AUGUST 1998 THROUGH JULY 1999[1]

Monitoring Location	Number of DO Values Rejected	Percent of DO Values Rejected
Linden	1,720	19.7
Simpson	1,377	15.8
Main	1,598	18.3
Devon	655	7.5
Lawrence	290	3.3
Addison	21	0.2
Fullerton	1,028	11.8
Division	761	8.7
Kinzie	19	0.2
Clark	349	4.0
Jackson	225	2.6
Loomis	687	7.9
I-55	1,548	17.7
Cicero	559	6.4
B&O RR	540	6.2
Route 83	2,157	24.7
Mile 302.6	1,022	11.7
Romeoville	237	2.7
Lockport	374	4.3
Route 83 (Cal-Sag)	323	3.7

[1]DO values were rejected based on quality control check and/or operational problems with monitor.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 3

MINIMUM, MAXIMUM, AND MEAN DISSOLVED OXYGEN VALUES MEASURED HOURLY IN THE CHICAGO WATERWAY SYSTEM DURING AUGUST 1998 THROUGH JULY 1999[1]

Monitoring Location	Waterway	DO Values (mg/L)		
		Minimum	Maximum	Mean
Linden	North Shore Channel	0.0	16.2	3.5
Simpson	North Shore Channel	0.0	15.0	3.6
Main	North Shore Channel	0.0	32.7	8.2
Devon	North Shore Channel	1.9	11.0	7.4
Lawrence	North Branch Chicago River	1.7	11.9	7.5
Addison	North Branch Chicago River	0.7	11.0	7.0
Fullerton	North Branch Chicago River	0.1	10.9	6.2
Division	North Branch Chicago River	0.3	10.5	6.5
Kinzie	North Branch Chicago River	0.2	10.8	6.3
Clark	Chicago River	3.4	12.8	8.2
Jackson	South Branch Chicago River	1.0	13.3	6.7
Loomis	South Branch Chicago River	0.5	12.6	6.9
I-55	South Fork of the South Branch	0.0	18.7	4.5
Cicero	Chicago Sanitary & Ship Canal	0.4	9.7	5.6
B&O RR	Chicago Sanitary & Ship Canal	0.7	9.9	6.6
Route 83	Chicago Sanitary & Ship Canal	0.4	10.4	5.9
Mile 302.6	Chicago Sanitary & Ship Canal	1.4	10.1	6.0
Romeoville	Chicago Sanitary & Ship Canal	1.0	10.2	5.5
Lockport	Chicago Sanitary & Ship Canal	1.2	10.0	5.4
Route 83	Cal-Sag Channel	1.1	11.5	6.1

[1]Dissolved oxygen was measured hourly using a YSI Model 6920 water quality monitor.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 4

NUMBER AND PERCENT OF DISSOLVED OXYGEN VALUES MEASURED ABOVE THE ILLINOIS POLLUTION CONTROL BOARD'S WATER QUALITY STANDARD IN THE CHICAGO WATERWAY SYSTEM DURING AUGUST 1998 THROUGH JULY 1999[1]

Monitoring Location	Waterway	IPCB DO Standard	Number of DO Values	Number of DO Values Above Standard	Percent of DO Values Above Standard
Linden	North Shore Channel	5.0	7,016	2,478	35
Simpson	North Shore Channel	5.0	7,359	2,667	36
Main	North Shore Channel	5.0	7,138	4,896	69
Devon	North Shore Channel	4.0	8,081	8,067	>99
Lawrence	North Branch Chicago River	4.0	8,446	8,407	>99
Addison	North Branch Chicago River	4.0	8,715	8,693	>99
Fullerton	North Branch Chicago River	4.0	7,708	7,205	93
Division	North Branch Chicago River	4.0	7,975	7,849	98
Kinzie	North Branch Chicago River	4.0	8,717	8,382	96
Clark	Chicago River	5.0	8,387	8,339	>99
Jackson	South Branch Chicago River	4.0	8,511	8,412	99
Loomis	South Branch Chicago River	4.0	8,049	7,897	98
I-55	South Fork South Branch	4.0	7,188	3,920	54
Cicero	Chicago Sanitary & Ship Canal	4.0	8,177	6,915	85

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 4 (Continued)

NUMBER AND PERCENT OF DISSOLVED OXYGEN VALUES MEASURED ABOVE THE ILLINOIS POLLUTION CONTROL BOARD'S WATER QUALITY STANDARD IN THE CHICAGO WATERWAY SYSTEM DURING AUGUST 1998 THROUGH JULY 1999[1]

Monitoring Location	Waterway	IPCB DO Standard	Number of DO Values	Number of DO Values Above Standard	Percent of DO Values Above Standard
B&O RR	Chicago Sanitary & Ship Canal	4.0	8,196	7,923	97
Route 83	Chicago Sanitary & Ship Canal	4.0	6,579	5,762	88
Mile 302.6	Chicago Sanitary & Ship Canal	4.0	7,714	7,012	91
Romeoville	Chicago Sanitary & Ship Canal	4.0	8,499	6,630	78
Lockport	Chicago Sanitary & Ship Canal	4.0	8,362	6,167	74
Route 83	Cal-Sag Channel	3.0	8,413	8,245	98

[1]Dissolved oxygen was measured hourly using a YSI Model 6920 water quality monitor.

Shore Channel to the Chicago River, the South Branch of the Chicago River, the South Fork of the South Branch of the Chicago River, the Chicago Sanitary and Ship Canal, the Grand Calumet River, the deep draft portion of the Little Calumet River, and the Cal-Sag Channel.

The IPCB has established water quality standards for DO in both General Use and Secondary Contact Waters. In General Use Waters, DO shall not be less than 6.0 mg/L during 16 hours of any 24 hour period, nor less than 5.0 mg/L at any time. In Secondary Contact Waters, DO shall not be less than 4.0 mg/L at any time except in the Cal-Sag Channel where the DO shall not be less than 3.0 mg/L at any time. For this report, we have selected the 5.0 mg/L DO standard for General Use Waters.

North Shore Channel

LINDEN STREET

The maximum DO value recorded at Linden Street in the North Shore Channel from August 1998 through July 1999 was 16.2 mg/L. The minimum DO value was 0.0 mg/L. During the twelve-month period, the mean DO concentration was 3.5 mg/L at Linden Street.

The IPCB requires that the DO concentration in those portions of the North Shore Channel classified as General Use Waters shall not be less than 5.0 mg/L at any time. From August 1998 through July 1999, only 2,478 of 7,016 DO values at Linden Street (35 percent) were above the IPCB General Use DO

standard. DO measurements below the 5.0 mg/L standard occurred in all months (Figure 2).

SIMPSON STREET

From August 1998 through July 1999, the DO concentration measured at Simpson Street in the North Shore Channel ranged from a low of 0.0 mg/L to a high of 15.1 mg/L. The mean DO value at Simpson Street was 3.6 mg/L during the twelve-month period.

The IPCB DO standard applicable to Simpson Street in the North Shore Channel is 5.0 mg/L. From August 1998 through July 1999, only 2,667 of 7,359 DO observations at Simpson Street (36 percent) were above the IPCB General Use DO Standard. DO measurements below the 5.0 mg/L standard occurred in all months (Figure 3).

MAIN STREET

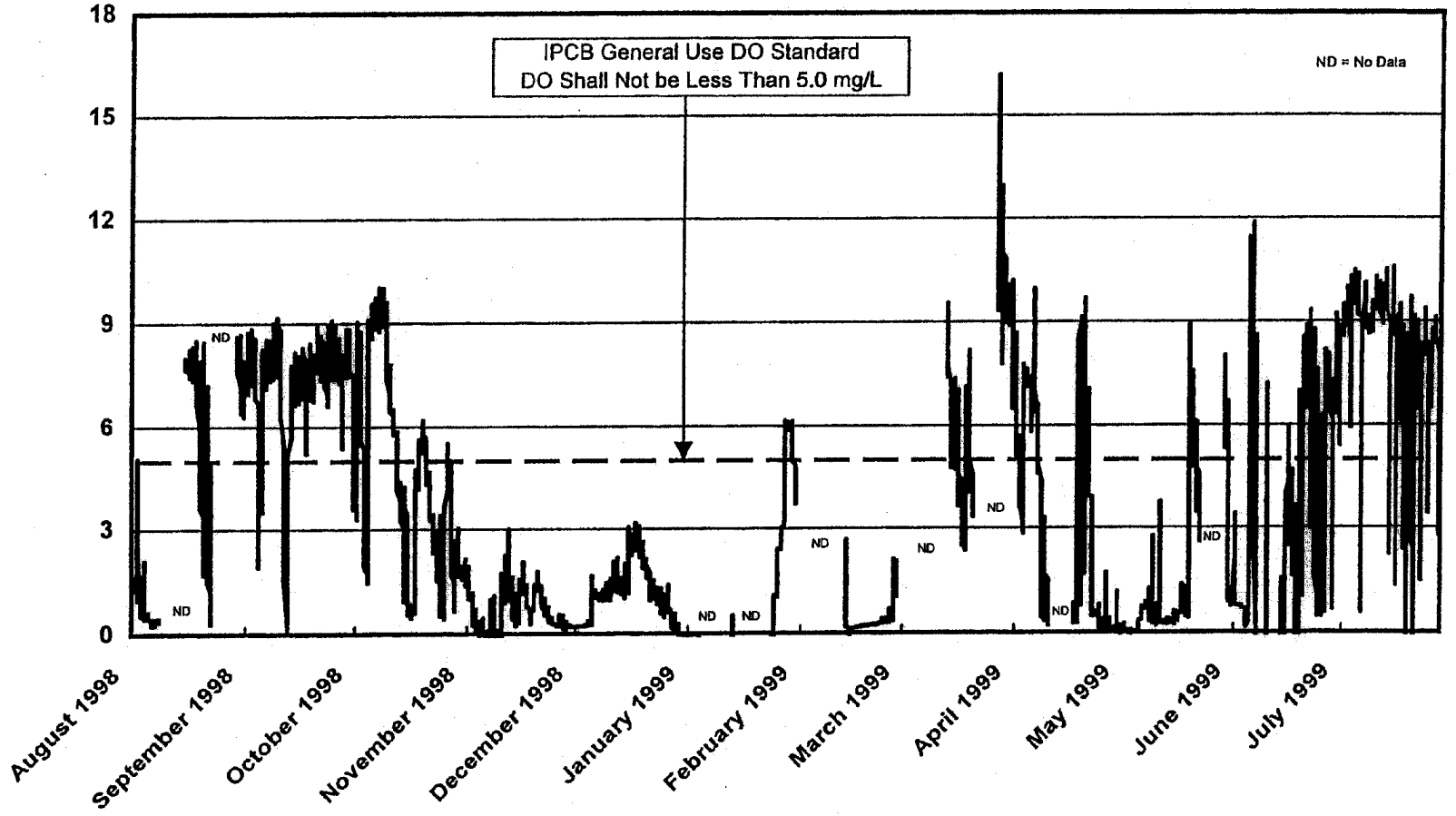
The maximum DO value recorded at Main Street in the North Shore Channel from August 1998 through July 1999 was 32.7 mg/L. The supersaturated DO value was measured during the day when sunlight was available for photosynthesis. The high DO resulted from an algal bloom. The minimum DO value was 0.0 mg/L. During the twelve-month period, the mean DO concentration was 8.2 mg/L at Main Street.

The IPCB requires that the DO concentration in those portions of the North Shore Channel classified as General Use Waters shall not be less than 5.0 mg/L at any time. From August

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 2

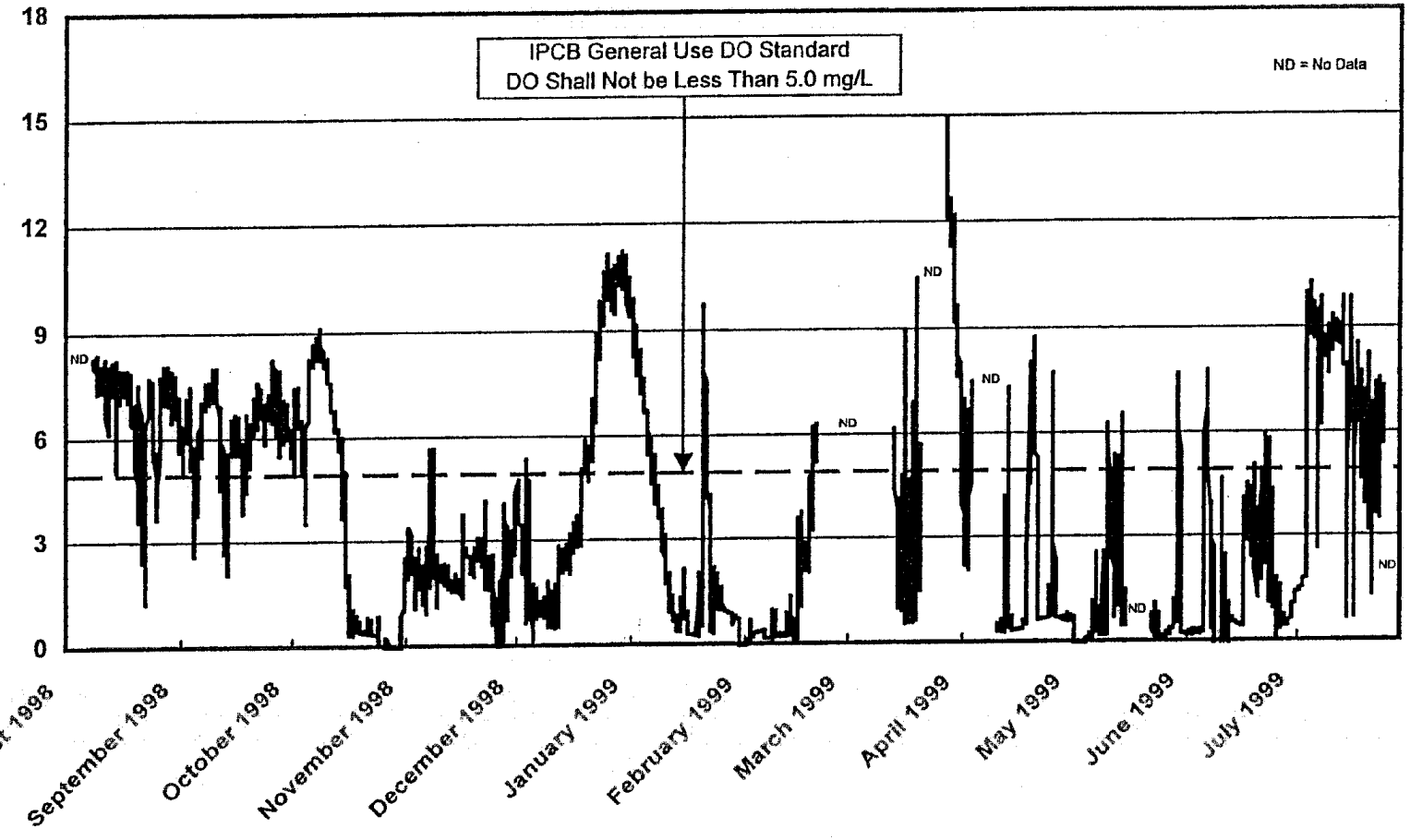
DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT LINDEN STREET
IN NORTH SHORE CHANNEL, AUGUST 1998 THROUGH JULY 1999



METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 3

DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT SIMPSON STREET
IN NORTH SHORE CHANNEL, AUGUST 1998 THROUGH JULY 1999



1998 through July 1999, only 4,896 of 7,138 DO values at Main Street (69 percent) were above the IPCB General Use DO standard. DO measurements below the 5.0 mg/L standard occurred in all months except November and February (Figure 4).

DEVON AVENUE

From August 1998 through July 1999, the DO concentration measured at Devon Avenue in the North Shore Channel ranged from a low of 1.9 mg/L to a high of 11.0 mg/L. The mean DO value at Devon Avenue was 7.4 mg/L during the twelve-month period.

The IPCB DO standard applicable to Devon Avenue in the North Shore Channel is 4.0 mg/L. From August 1998 through July 1999, 8,067 of 8,081 DO observations at Devon Avenue (>99 percent) were above the IPCB Secondary Contact DO standard. DO measurements below the 4.0 mg/L standard occurred in January, June, and July (Figure 5).

North Branch Chicago River

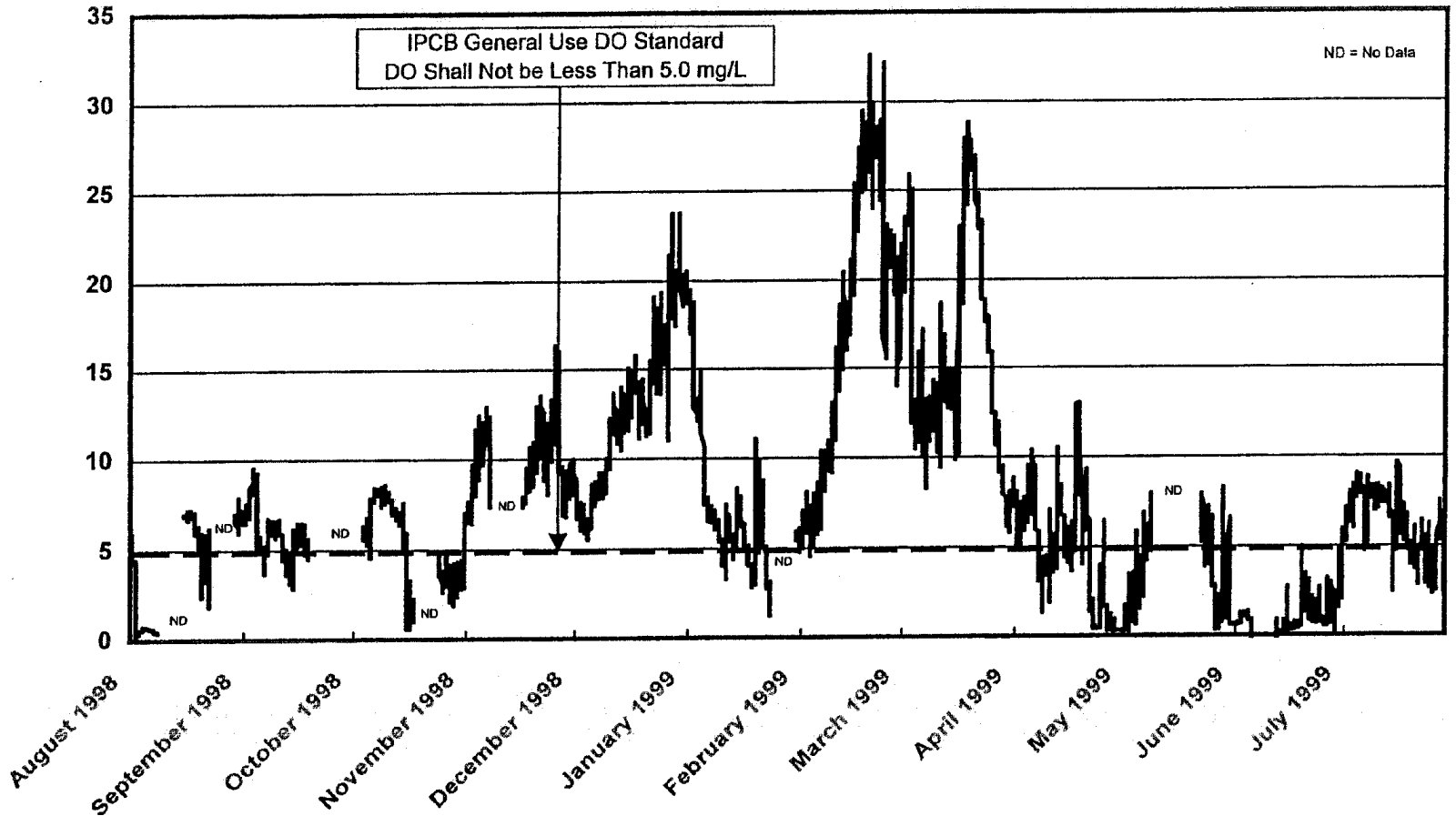
LAWRENCE AVENUE

The maximum DO value recorded at Lawrence Avenue in the North Branch of the Chicago River from August 1998 through July 1999 was 11.9 mg./L. The minimum DO value was 1.7 mg/L.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 4

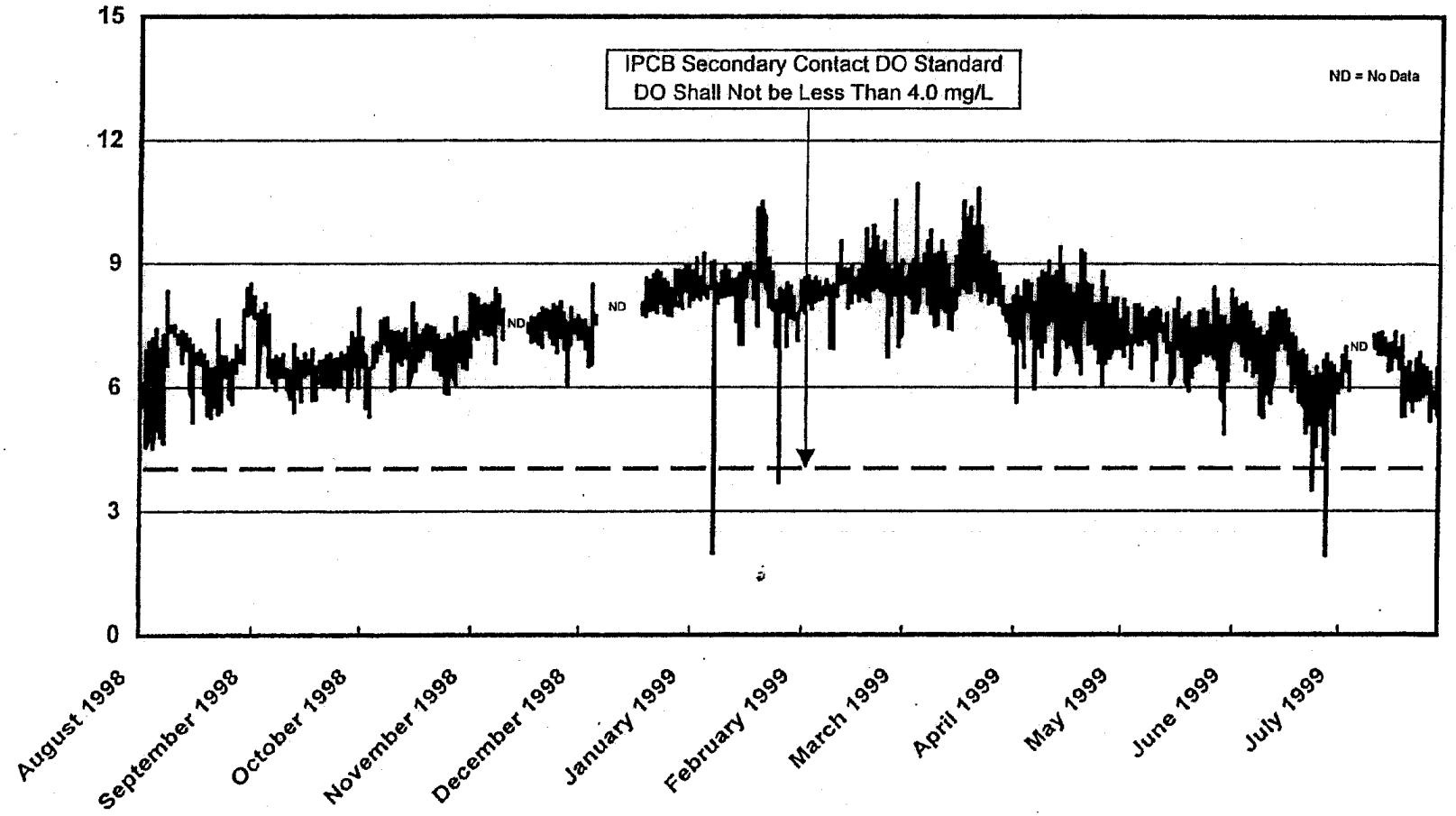
DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT MAIN STREET
IN NORTH SHORE CHANNEL, AUGUST 1998 THROUGH JULY 1999



METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 5

DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT DEVON AVENUE
IN NORTH SHORE CHANNEL, AUGUST 1998 THROUGH JULY 1999



During the twelve-month period, the mean DO concentration was 7.5 mg/L at Lawrence Avenue.

The IPCB requires that the DO concentration in those portions of the North Branch of the Chicago River classified as Secondary Contact Waters shall not be less than 4.0 mg/L at any time. From August 1998 through July 1999, 8,407 of 8,446 DO values at Lawrence Avenue (>99 percent) were above the IPCB Secondary Contact DO standard. DO measurements below the 4.0 mg/L standard occurred in May through July (Figure 6).

ADDISON STREET

From August 1998 through July 1999, the DO concentration measured at Addison Street in the North Branch of the Chicago River ranged from a low of 0.7 mg/L to a high of 11.0 mg/L. The mean DO value at Addison Street was 7.0 mg/L during the twelve-month period.

The IPCB DO standard applicable to Addison Street in the North Branch of the Chicago River is 4.0 mg/L. From August 1998 through July 1999, 8,693 of 8,715 DO observations at Addison Street (>99 percent) were above the IPCB Secondary Contact DO standard. DO measurements below the 4.0 mg/L standard occurred in October, May, and July (Figure 7).

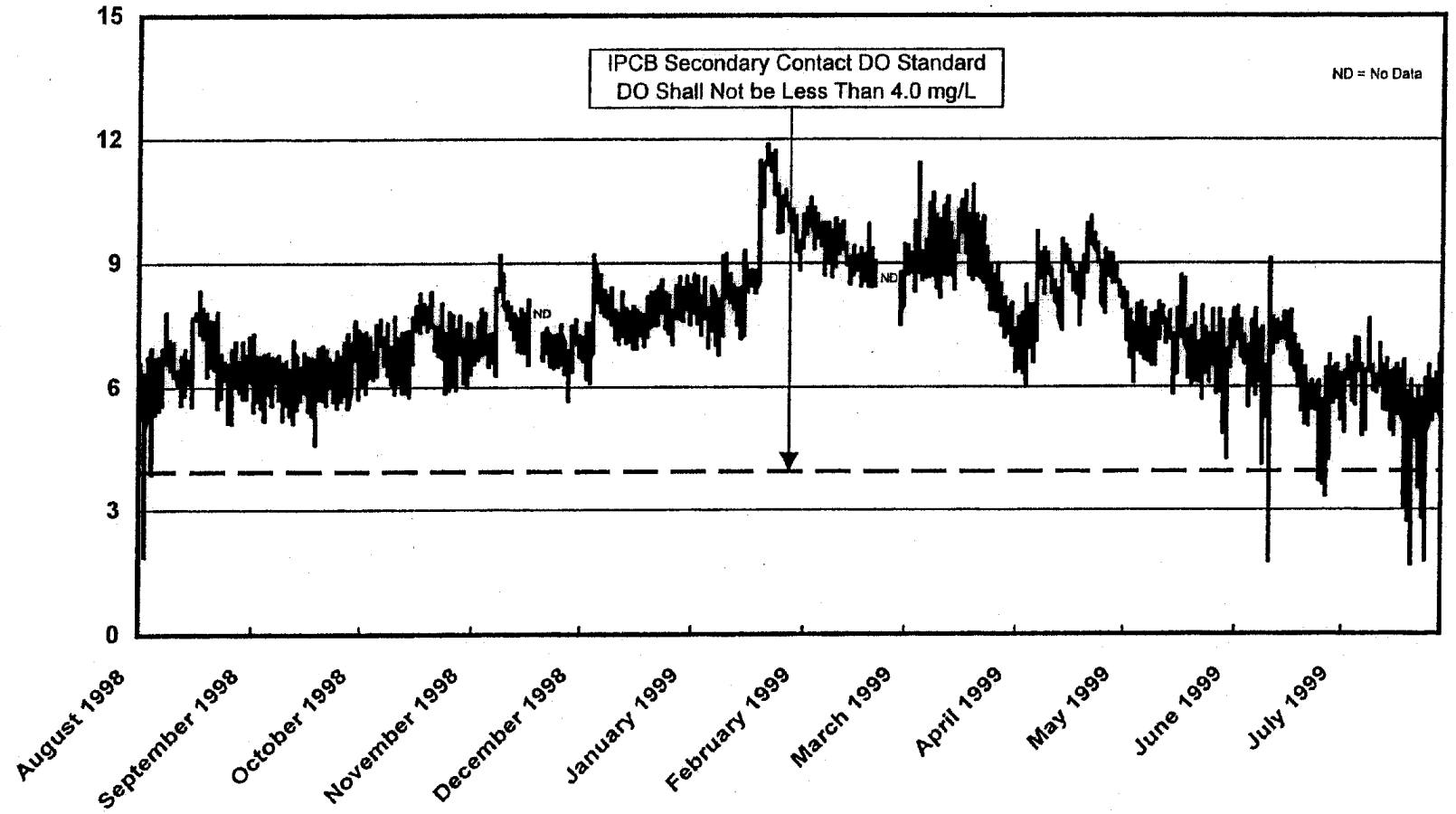
FULLERTON AVENUE

The maximum DO value recorded at Fullerton Avenue in the North Branch of the Chicago River from August 1998 through July 1999 was 10.9 mg/L. The minimum DO value was 0.1 mg/L.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 6

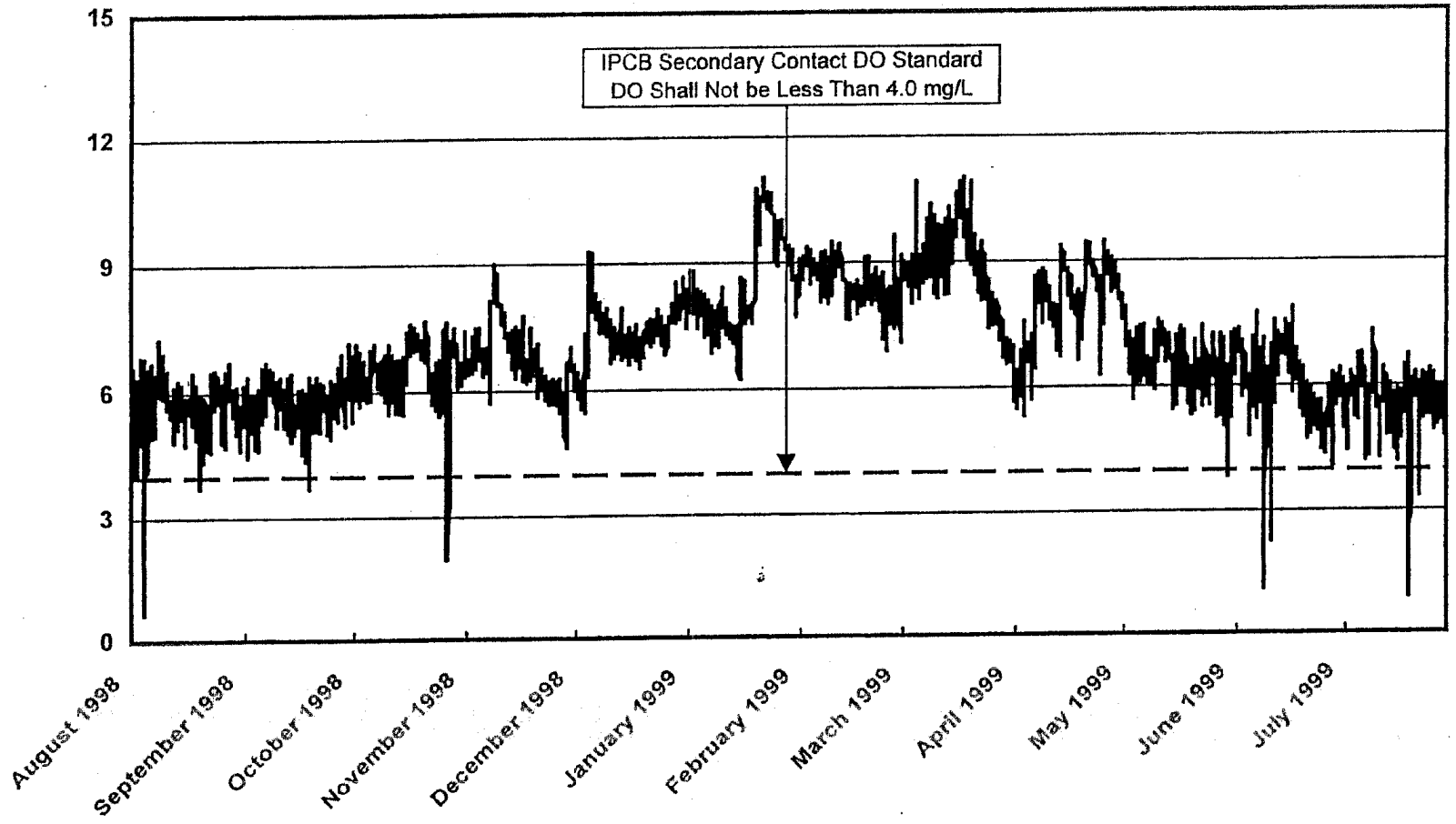
DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT LAWRENCE AVENUE
IN NORTH BRANCH CHICAGO RIVER, AUGUST 1998 THROUGH JULY 1999



METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 7

DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT ADDISON STREET
IN NORTH BRANCH CHICAGO RIVER, AUGUST 1998 THROUGH JULY 1999



During the twelve-month period, the mean DO concentration was 6.2 mg/L at Fullerton Avenue.

The IPCB requires that the DO concentration in those portions of the North Branch of the Chicago River classified as Secondary Contact Waters shall not be less than 4.0 mg/L at any time. From August 1998 through July 1999, 7,205 of 7,708 DO values at Fullerton Avenue (93 percent) were above the IPCB Secondary Contact DO standard. DO measurements below the 4.0 mg/L standard occurred in August, October, and May through July (Figure 8).

DIVISION STREET

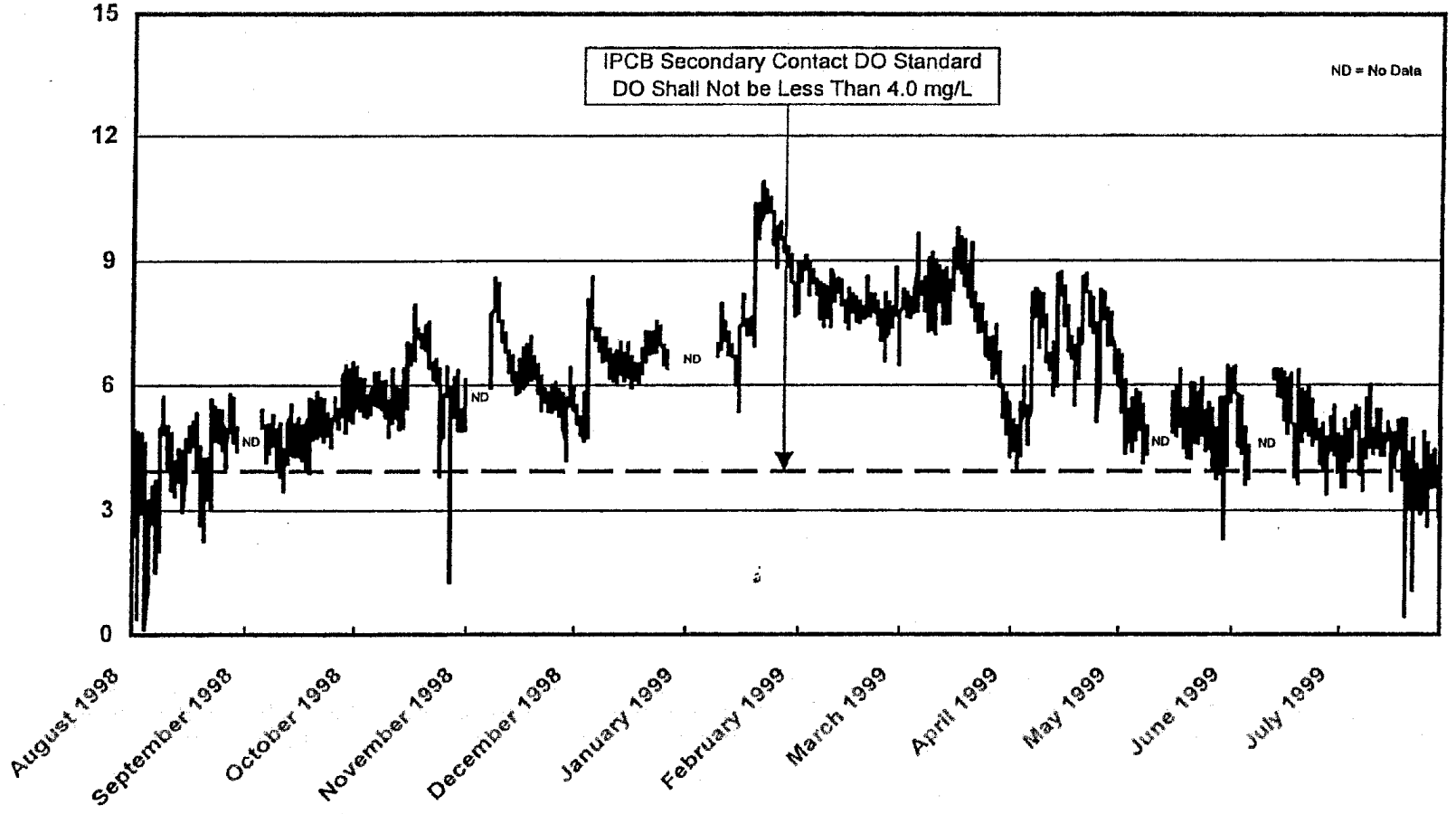
From August 1998 through July 1999, the DO concentration measured at Division Street in the North Branch of the Chicago River ranged from a low of 0.3 mg/L to a high of 10.5 mg/L. The mean DO value at Division Street was 6.5 mg/L during the twelve-month period.

The IPCB DO standard applicable to Division Street in the North Branch of the Chicago River is 4.0 mg/L. From August 1998 through July 1999, 7,849 of 7,975 DO observations at Division Street (98 percent) were above the Secondary Contact DO standard. DO measurements below the 4.0 mg/L standard occurred in August through October and May through July (Figure 9).

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 8

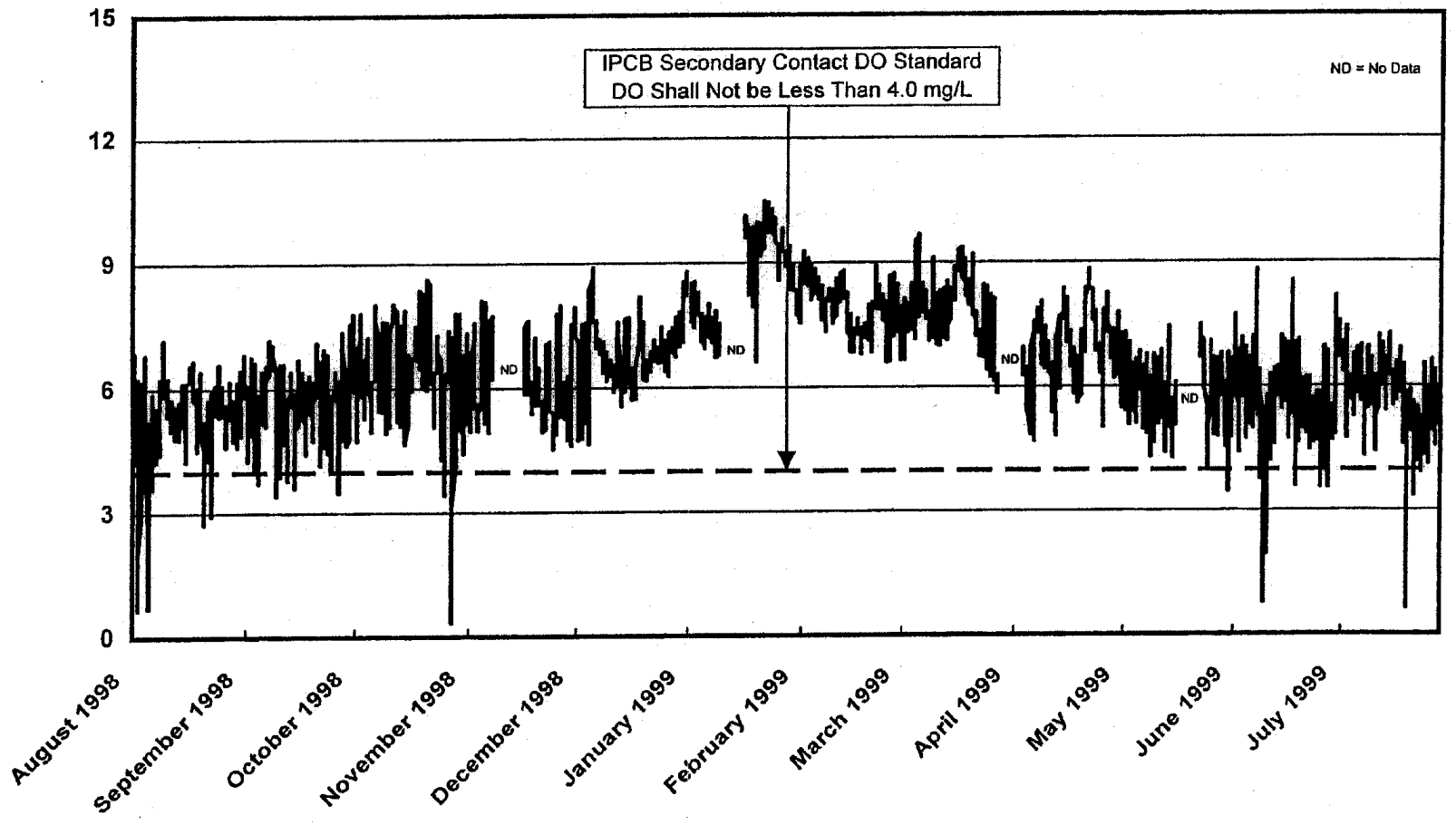
DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT FULLERTON AVENUE
IN NORTH BRANCH CHICAGO RIVER, AUGUST 1998 THROUGH JULY 1999



METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 9

DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT DIVISION STREET
IN NORTH BRANCH CHICAGO RIVER, AUGUST 1998 THROUGH JULY 1999



KINZIE STREET

The maximum DO value recorded at Kinzie Street in the North Branch of the Chicago River from August 1998 through July 1999 was 10.8 mg/L. The minimum DO value was 0.2 mg/L. During the twelve-month period, the mean DO concentration was 6.3 mg/L at Kinzie Street.

The IPCB requires that the DO concentration in those portions of the North Branch of the Chicago River classified as Secondary Contact Waters shall not be less than 4.0 mg/L at any time. From August 1998 through July 1999, 8,382 of 8,717 DO values at Kinzie Street (96 percent) were above the IPCB Secondary Contact DO standard. DO measurements below the 4.0 mg/L standard occurred in August through October and May through July (Figure 10).

Chicago River

CLARK STREET

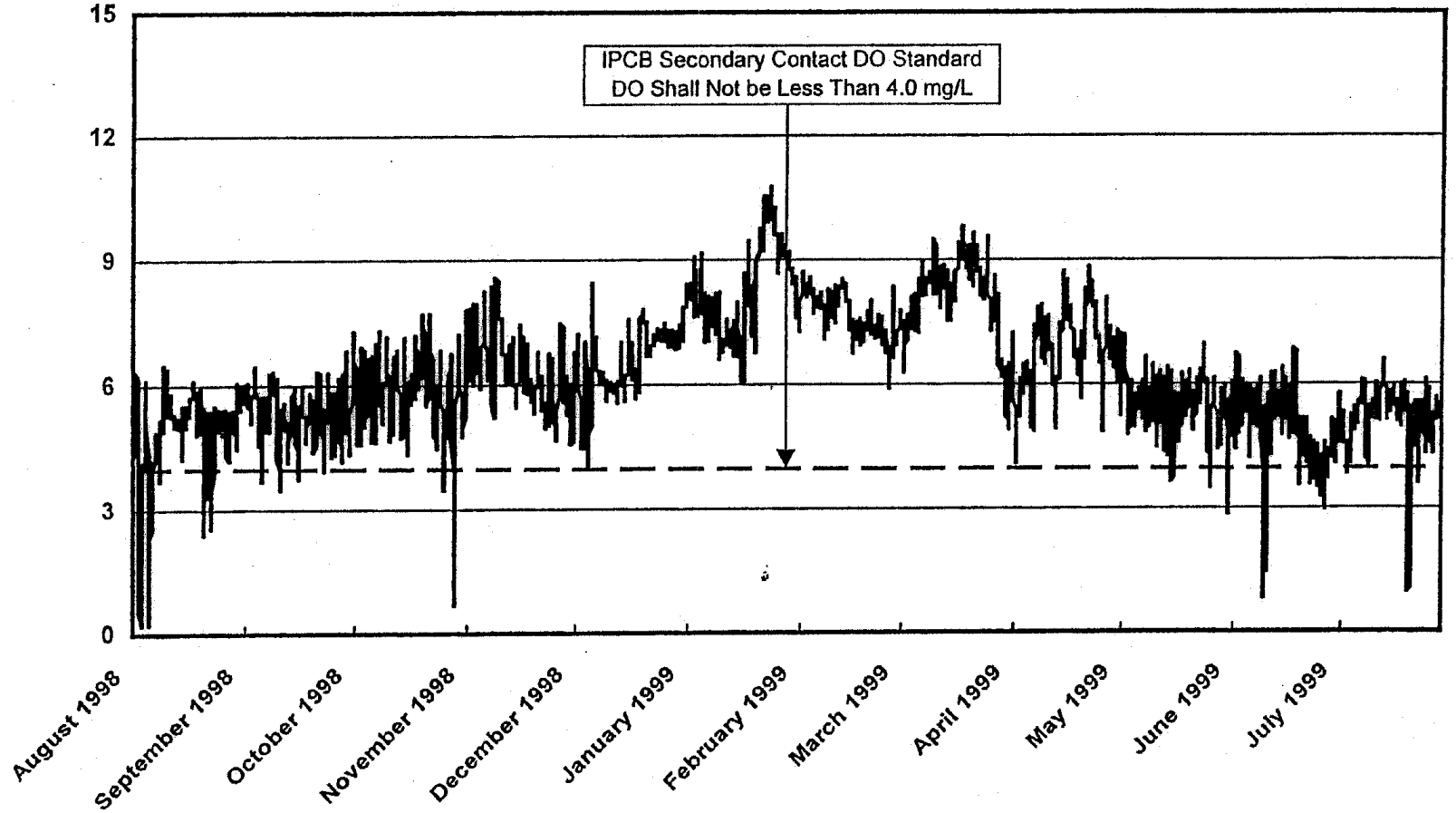
From August 1998 through July 1999, the DO concentration measured at Clark Street in the Chicago River ranged from a low of 3.4 mg/L to a high of 12.8 mg/L. The mean DO value at Clark Street was 8.2 mg/L during the twelve-month period.

The IPCB DO standard applicable to Clark Street in the Chicago River is 5.0 mg/L. From August 1998 through July 1999, 8,339 of 8,387 DO observations at Clark Street (>99 percent) were above the IPCB General Use DO standard. DO meas-

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 10

DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT KINZIE STREET
IN NORTH BRANCH CHICAGO RIVER, AUGUST 1998 THROUGH JULY 1999



urements below the 5.0 mg/L standard occurred in October and June (Figure 11).

South Branch Chicago River

JACKSON BOULEVARD

The maximum DO value recorded at Jackson Boulevard in the South Branch of the Chicago River from August 1998 through July 1999 was 13.3 mg/L. The minimum DO value was 1.0 mg/L. During the twelve-month period, the mean DO concentration was 6.7 mg/L at Jackson Boulevard.

The IPCB requires that the DO concentration in the South Branch of the Chicago River shall not be less than 4.0 mg/L at any time. From August 1998 through July 1999, 8,412 of 8,511 DO values at Jackson Boulevard (99 percent) were above the IPCB Secondary Contact DO standard. DO measurements below the 4.0 mg/L standard occurred in August, October, and May through July (Figure 12).

LOOMIS STREET

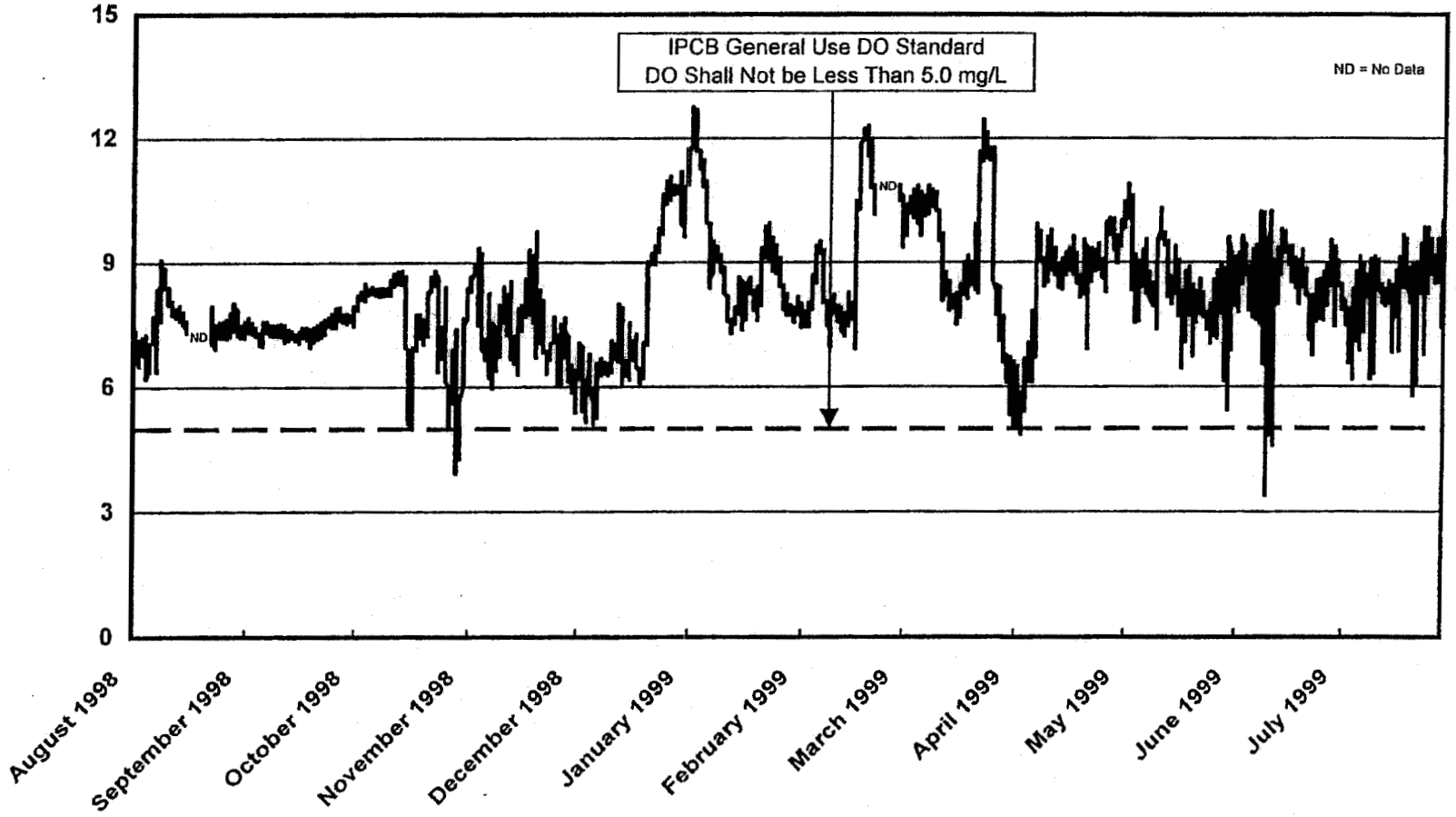
From August 1998 through July 1999, the DO concentration measured at Loomis Street in the South Branch of the Chicago River ranged from a low of 0.5 mg/L to a high of 12.6 mg/L. The mean DO value at Loomis Street was 6.9 mg/L during the twelve-month period.

The IPCB DO standard applicable to Loomis Street in the South Branch of the Chicago River is 4.0 mg/L. From August 1998 through July 1999, 7,897 of 8,049 DO observations at Loo-

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 11

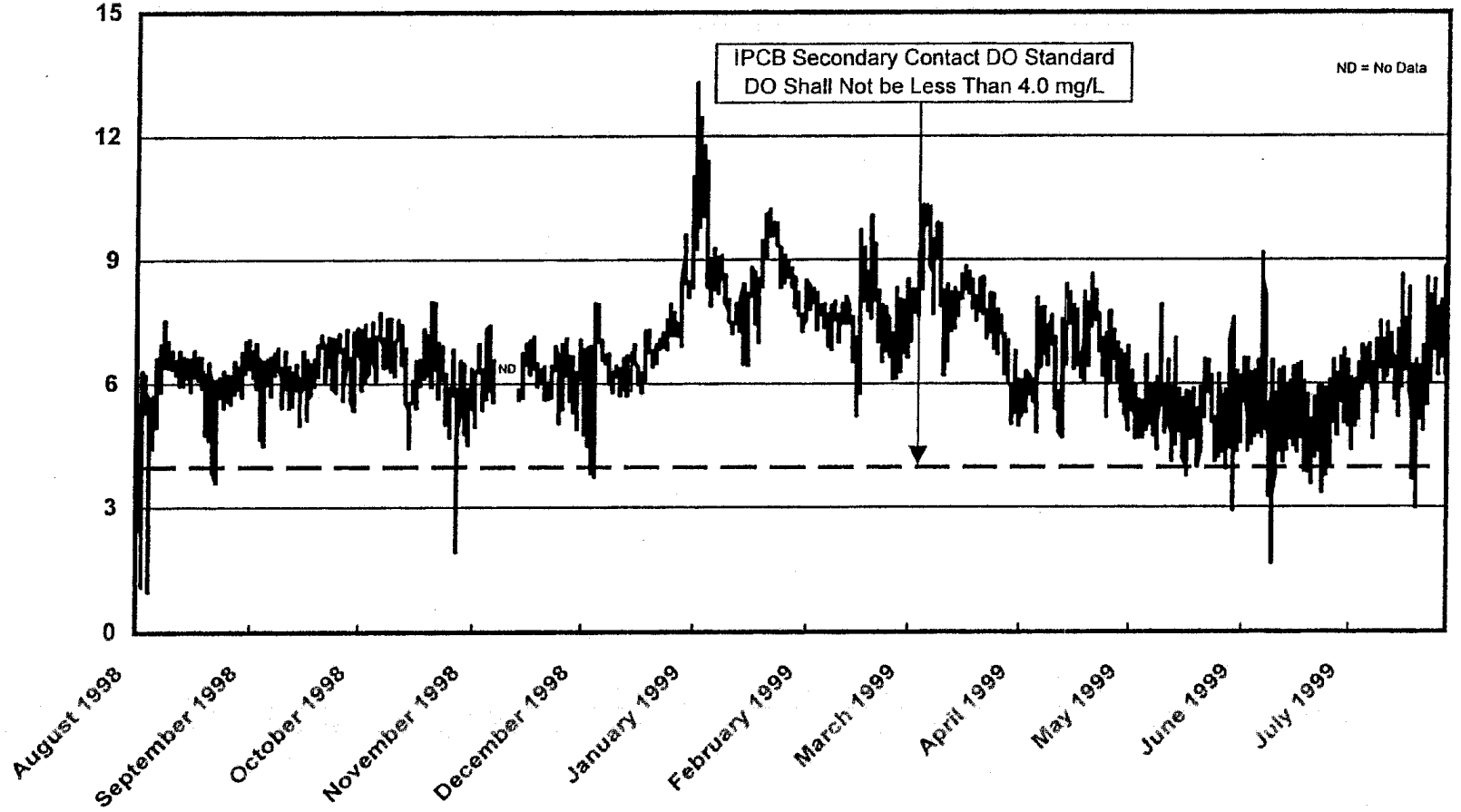
DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT CLARK STREET
IN CHICAGO RIVER, AUGUST 1998 THROUGH JULY 1999



METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 12

DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT JACKSON BOULEVARD
IN SOUTH BRANCH CHICAGO RIVER, AUGUST 1998 THROUGH JULY 1999



mis Street (98 percent) were above the IPCB Secondary Contact DO standard. DO measurements below the 4.0 mg/L standard occurred in August, October, November, May, and June (Figure 13).

South Fork of the South Branch Chicago River

INTERSTATE HIGHWAY 55 (I-55)

The maximum DO value recorded at I-55 in the South Fork of the South Branch of the Chicago River from August 1998 through July 1999 was 18.7 mg/L. The high DO value resulted from photosynthesis. The minimum DO value was 0.0 mg/L. During the twelve-month period, the mean DO concentration was 4.5 mg/L at I-55.

The IPCB requires that the DO concentration in the South Fork of the South Branch of the Chicago River shall not be less than 4.0 mg/L at any time. From August 1998 through July 1999, 3,920 of 7,188 DO values at I-55 (54 percent) were above the IPCB Secondary Contact DO standard. DO measurements below the 4.0 mg/L standard occurred in every month except February and March (Figure 14).

Chicago Sanitary and Ship Canal

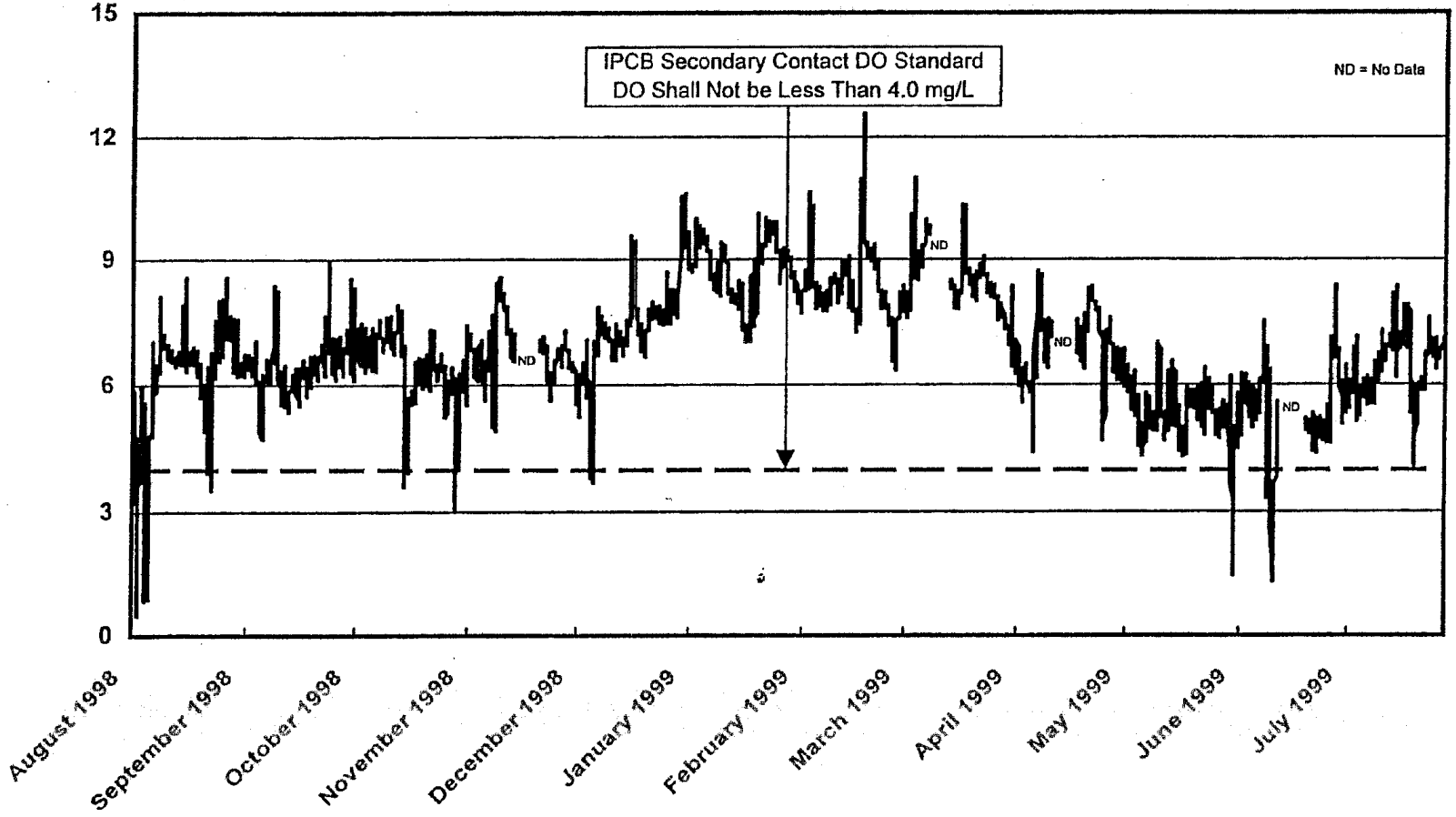
CICERO AVENUE

From August 1998 through July 1999, the DO concentration measured at Cicero Avenue in the Chicago Sanitary and Ship Canal ranged from a low of 0.4 mg/L to a high of 9.7 mg/L. The

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 13

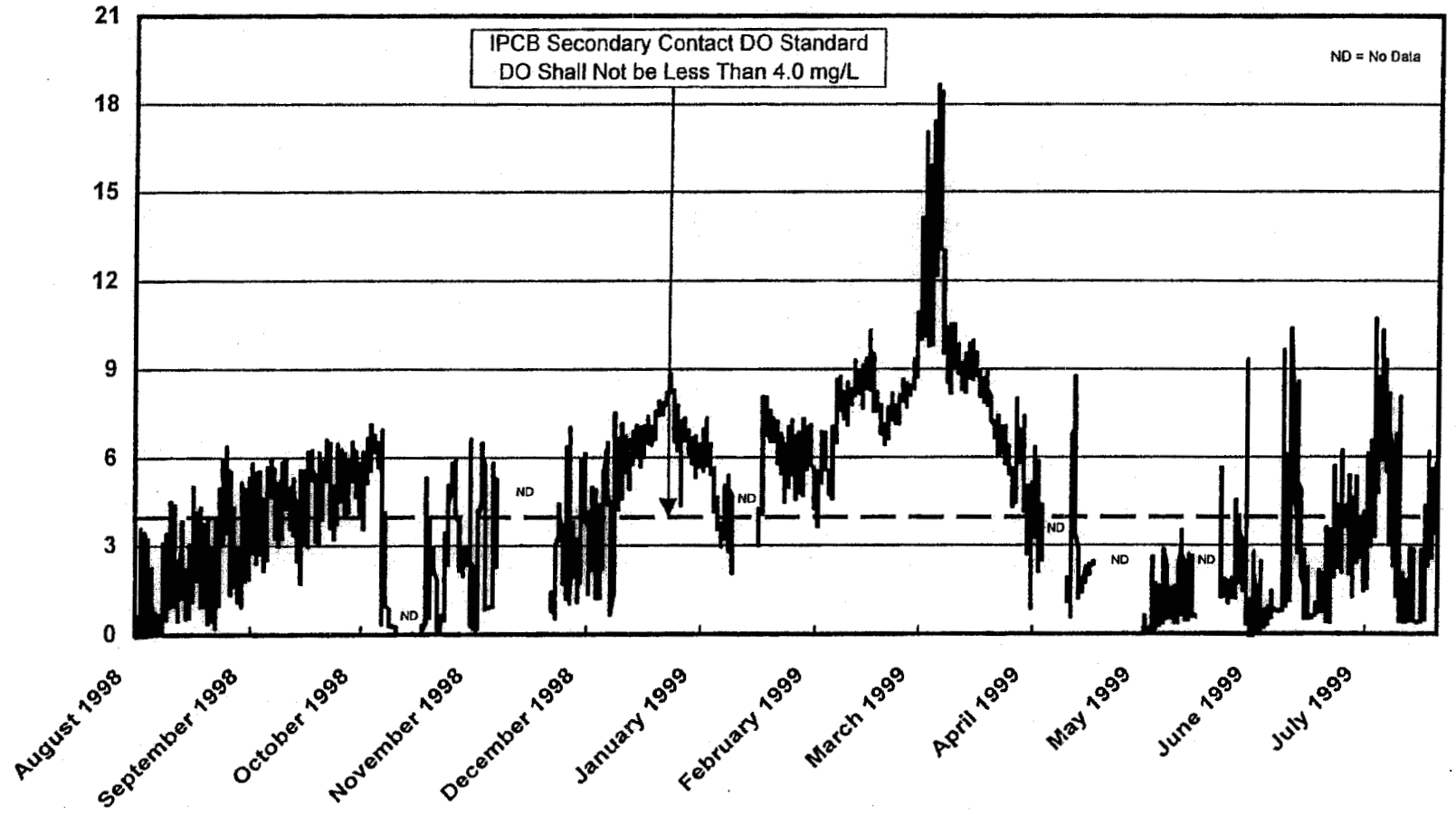
DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT LOOMIS STREET
IN SOUTH BRANCH CHICAGO RIVER, AUGUST 1998 THROUGH JULY 1999



METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 14

DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT INTERSTATE HIGHWAY 55
IN BUBBLY CREEK, AUGUST 1998 THROUGH JULY 1999



mean DO value at Cicero Avenue was 5.6 mg/L during the twelve-month period.

The IPCB DO standard applicable to Cicero Avenue in the Chicago Sanitary and Ship Canal is 4.0 mg/L. From August 1998 through July 1999, 6,915 of 8,177 DO observations at Cicero Avenue (85 percent) were above the IPCB Secondary Contact DO standard. DO measurements below the 4.0 mg/L standard occurred in August, October, November, and April through July (Figure 15).

B&O CENTRAL RAILROAD

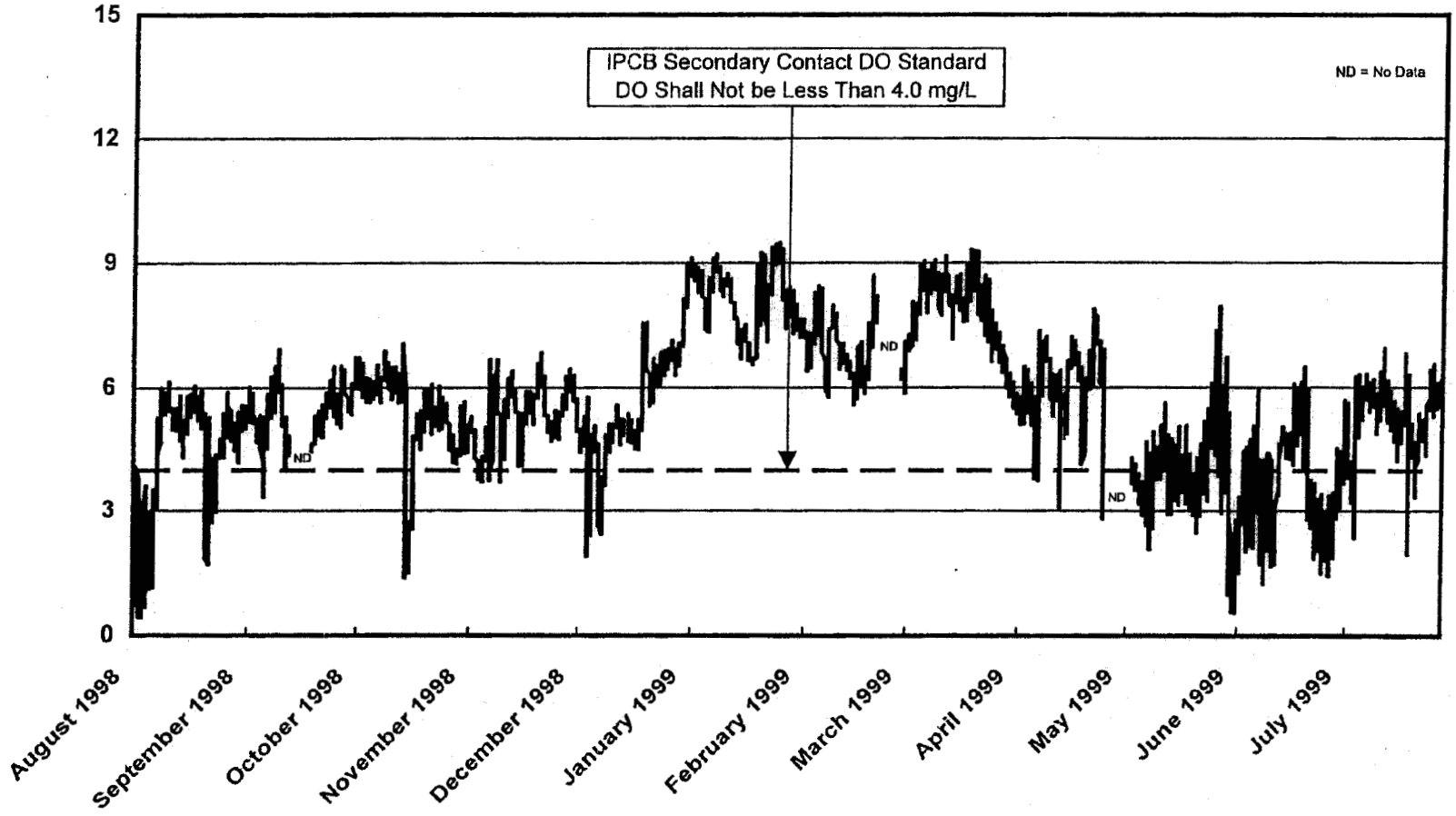
The maximum DO value recorded at B&O Central Railroad in the Chicago Sanitary and Ship Canal from August 1998 through July 1999 was 9.9 mg/L. The minimum DO value was 0.7 mg/L. During the twelve-month period, the mean DO concentration was 6.6 mg/L at B&O Central Railroad

The IPCB requires that the DO concentration in the Chicago Sanitary and Ship Canal shall not be less than 4.0 mg/L at any time. From August 1998 through July 1999, 7,923 of 8,196 DO values at B&O Central Railroad (97 percent) were above the IPCB Secondary Contact DO standard. DO measurements below the 4.0 mg/L standard occurred in August, October, and May through July (Figure 16).

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 15

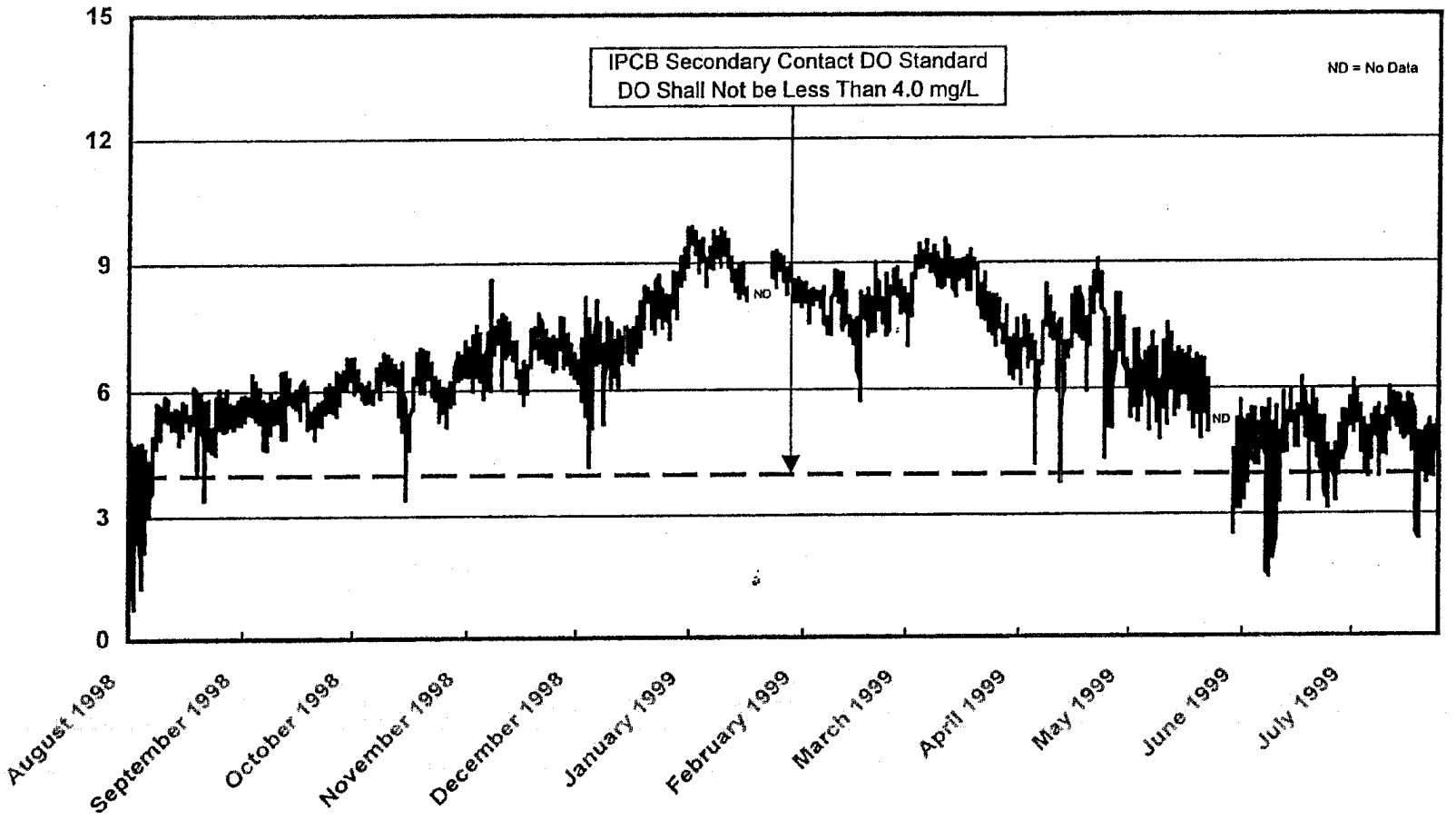
DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT CICERO AVENUE
IN CHICAGO SANITARY & SHIP CANAL, AUGUST 1998 THROUGH JULY 1999



METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 16

DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT B&O CENTRAL RAILROAD
IN CHICAGO SANITARY & SHIP CANAL, AUGUST 1998 THROUGH JULY 1999



ROUTE 83

From August 1998 through July 1999, the DO concentration measured at Route 83 in the Chicago Sanitary and Ship Canal ranged from a low of 0.4 mg/L to a high of 10.4 mg/L. The mean DO value at Route 83 was 5.9 mg/L during the twelve-month period.

The IPCB DO standard applicable to Route 83 in the Chicago Sanitary and Ship Canal is 4.0 mg/L. From August 1998 through July 1999, 5,762 of 6,579 DO observations at Route 83 (88 percent) were above the IPCB Secondary Contact DO standard. DO measurements below the 4.0 mg/L standard occurred in April, June, and July (Figure 17).

RIVER MILE 302.6

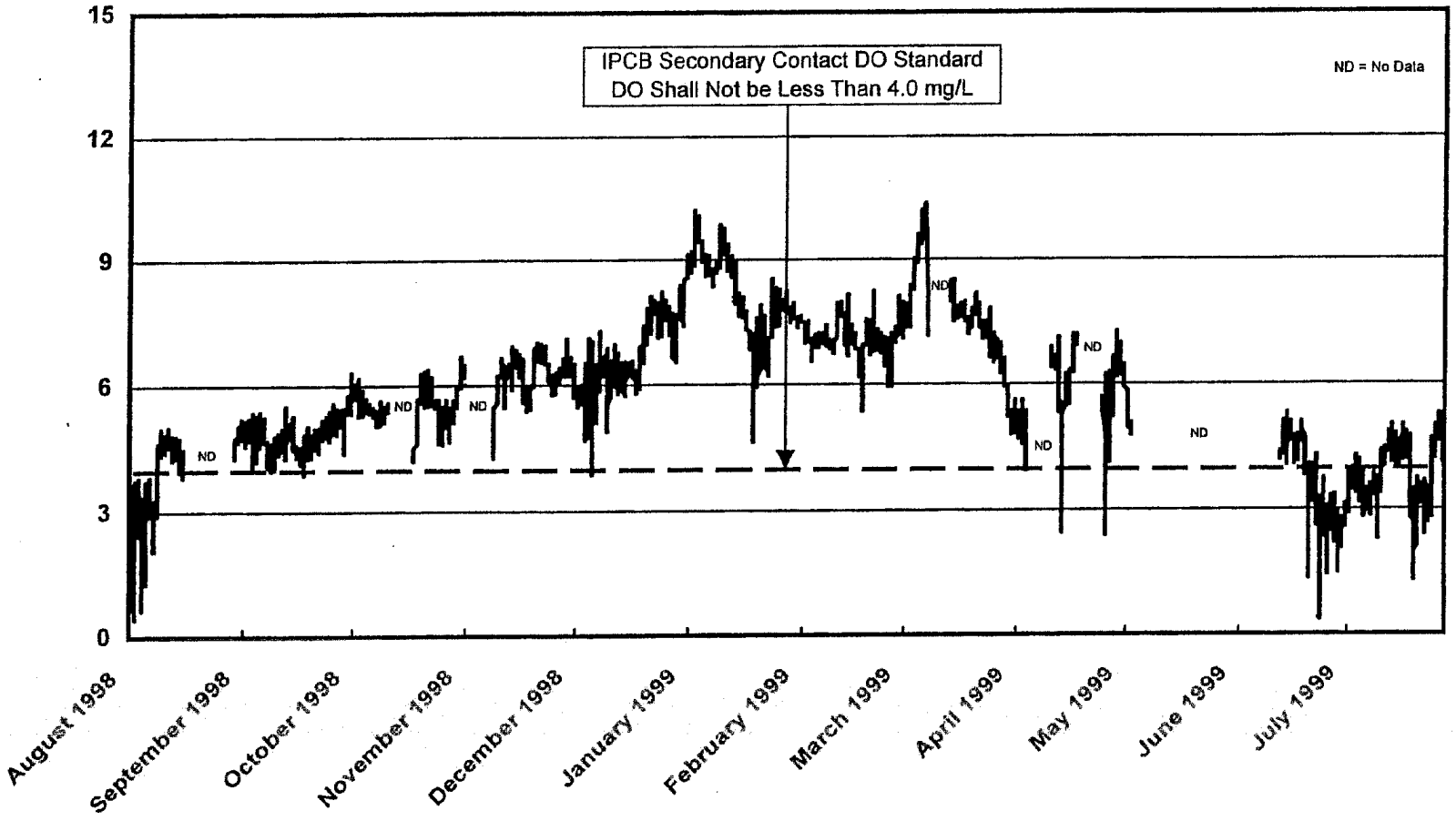
The maximum DO value recorded at River Mile 302.6 in the Chicago Sanitary and Ship Canal from August 1998 through July 1999 was 10.1 mg/L. The minimum DO value was 1.4 mg/L. During the twelve-month period, the mean DO concentration was 6.0 mg/L at river Mile 302.6.

The IPCB requires that the DO concentration in the Chicago Sanitary and Ship Canal shall not be less than 4.0 mg/L at any time. From August 1998 through July 1999, 7,012 of 7,714 DO values at River Mile 302.6 (91 percent) were above the IPCB Secondary Contact DO standard. DO measurements below the 4.0 mg/L standard occurred during August, October, and April through June (Figure 18).

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 17

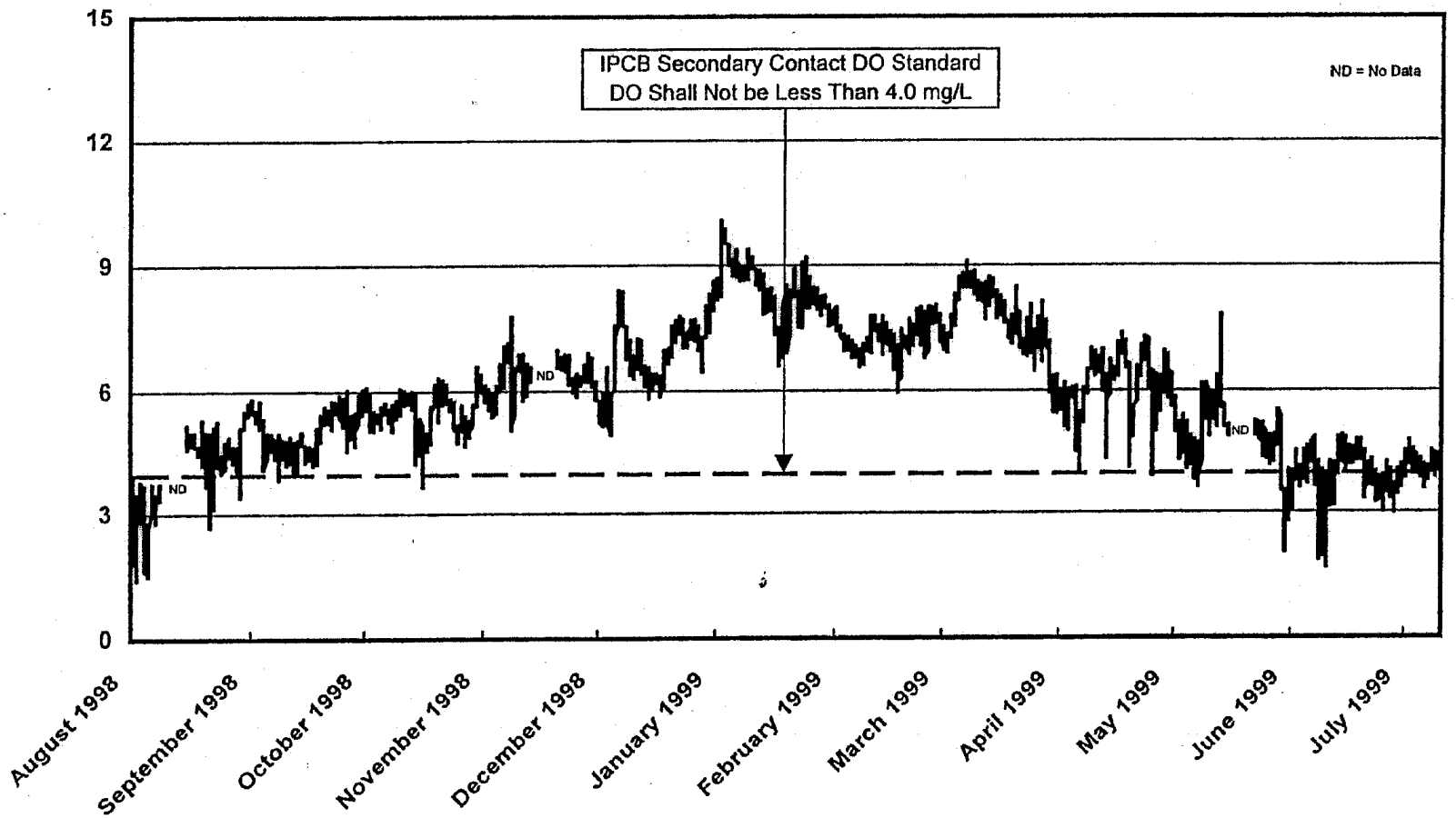
DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT ROUTE 83
IN CHICAGO SANITARY & SHIP CANAL, AUGUST 1998 THROUGH JULY 1999



METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 18

DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT RIVER MILE 302.6
IN CHICAGO SANITARY & SHIP CANAL, AUGUST 1998 THROUGH JULY 1999



ROMEOVILLE ROAD

From August 1998 through July 1999, the DO concentration measured at Romeoville Road in the Chicago Sanitary and Ship Canal ranged from a low of 1.0 mg/L to a high of 10.2 mg/L. The mean DO value at Romeoville Road was 5.5 mg/L during the twelve-month period.

The IPCB DO standard applicable to Romeoville Road in the Chicago Sanitary and Ship Canal is 4.0 mg/L. From August 1998 through July 1999, 6,630 of 8,499 DO observations at Romeoville Road (78 percent) were above the IPCB Secondary Contact DO standard. DO measurements below the 4.0 mg/L standard occurred in August through October and May through July (Figure 19).

LOCKPORT

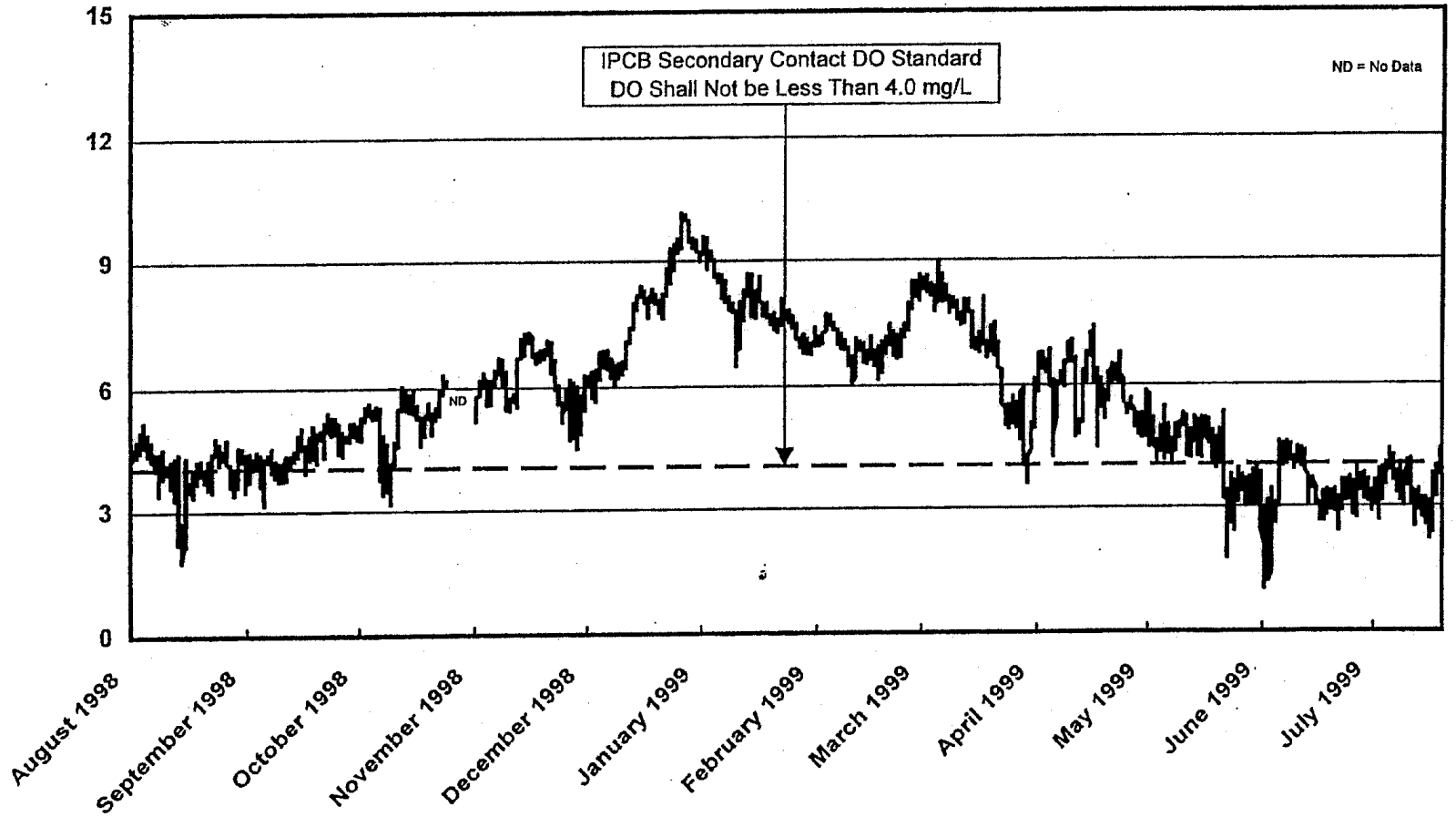
The maximum DO value recorded at Lockport in the Chicago Sanitary and Ship Canal from August 1998 through July 1999 was 10.0 mg/L. The minimum DO value was 1.2 mg/L. During the twelve-month period, the mean DO concentration was 5.4 mg/L at Lockport.

The IPCB requires that the DO concentration in the Chicago Sanitary and Ship Canal shall not be less than 4.0 mg/L at any time. From August 1998 through July 1999, 6,167 of 8,362 DO values at Lockport (74 percent) were above the IPCB Secondary Contact DO standard. DO measurements below the 4.0

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 19

DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT ROMEOVILLE ROAD
IN CHICAGO SANITARY & SHIP CANAL, AUGUST 1998 THROUGH JULY 1999



mg/L standard occurred during August, September, and May through July (Figure 20).

Cal-Sag Channel

ROUTE 83

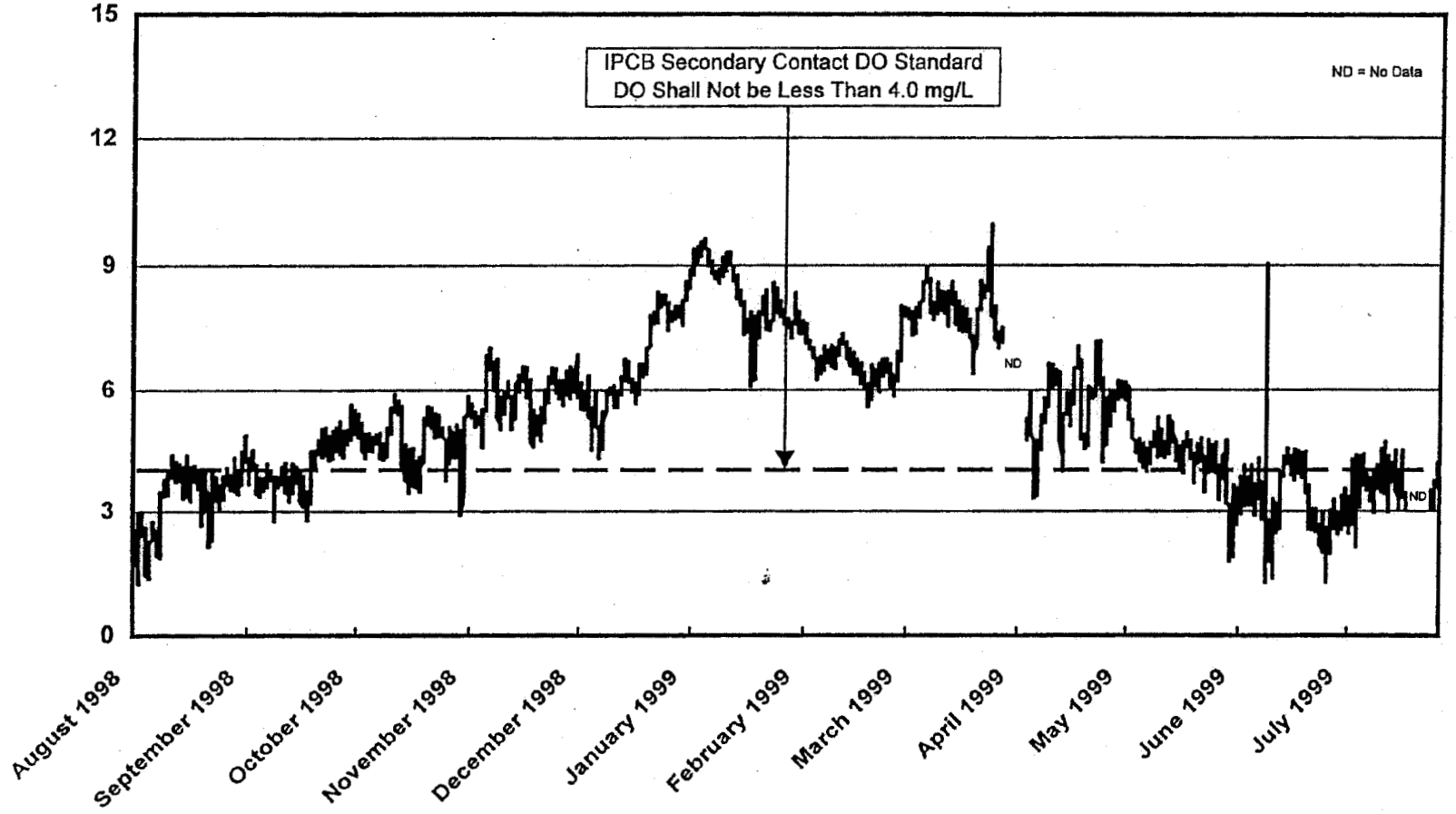
From August 1998 through July 1999, the DO concentration measured at Route 83 in the Cal-Sag Channel ranged from a low of 1.1 mg/L to a high of 11.5 mg/L. The mean DO value at Route 83 was 6.1 mg/L during the twelve-month period.

The IPCB DO standard applicable to Route 83 in the Cal-Sag Channel is 3.0 mg/L. From August 1998 through July 1999, 8,245 of 8,413 DO observations at Route 83 (98 percent) were above the IPCB Secondary Contact DO standard. DO measurements below the 3.0 mg/L standard occurred during August, and May through June (Figure 21).

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 20

DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT LOCKPORT POWER HOUSE
IN CHICAGO SANITARY & SHIP CANAL, AUGUST 1998 THROUGH JULY 1999



METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 21

DISSOLVED OXYGEN CONCENTRATION MEASURED HOURLY AT ROUTE 83
IN CAL-SAG CHANNEL, AUGUST 1998 THROUGH JULY 1999