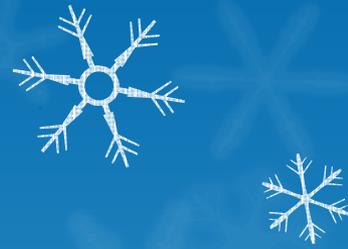


Evaluation of the Impact of Lake Discretionary Diversion on Water Quality in the Chicago Area Waterways System

Charles "Steve" Melching, Ph.D., P.E.

Greenfield, WI 53221



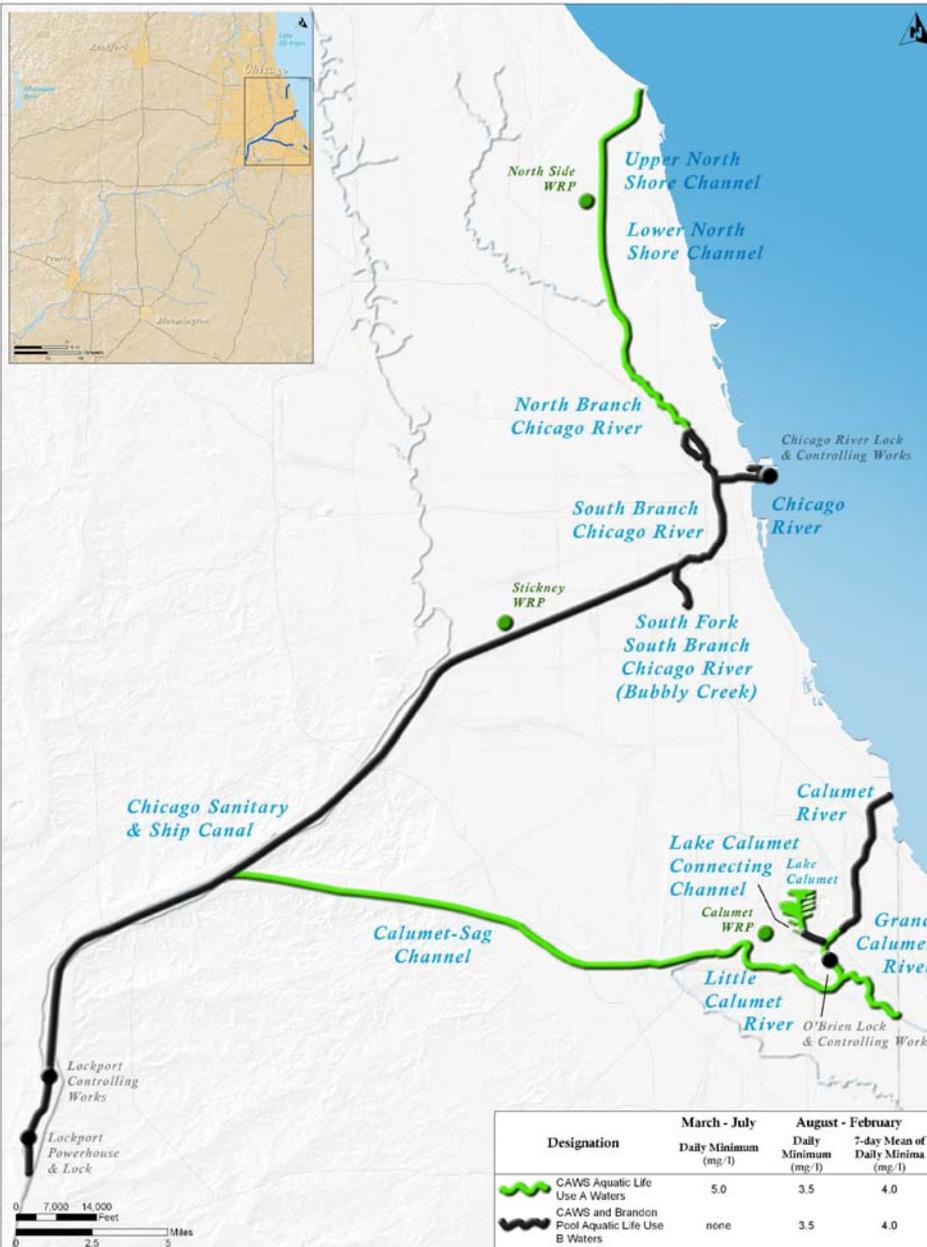
Project Goal

- Using the District's Existing Resources to Maximize Compliance with the Dissolved Oxygen (DO) Standards Proposed by the Illinois Environmental Protection Agency in 2007.

IEPA (2007) DO Criteria

○ Min DO = 3.5 (August-February), 5 mg/L (March-July); 7-day average of Min DO = 4 mg/L

○ Min DO = 3.5 mg/L ; 7-day average of Min DO = 4 mg/L



Chicago Area Waterway Aquatic Life Use Designations

Development of an Integrated Strategy to Meet Dissolved Oxygen Water Quality Standards for the Chicago Area Waterway System (CAWS) Expectations Workshop, January 9, 2008

SEPA Stations (4 & 5)



Instream Aeration Stations



Webster Avenue



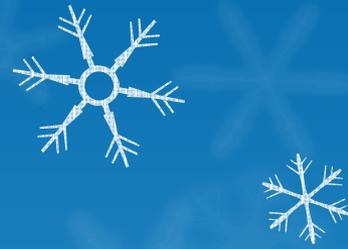
Devon Avenue

Discretionary Diversion from Lake Michigan

- The District is allowed by the State of Illinois to take a direct diversion from Lake Michigan to maintain the Chicago Area Waterways System (CAWS) in a “reasonably satisfactory sanitary condition”
 - Through Water Year 2014 the amount of the discretionary diversion is limited to an annual average of 270 cfs
 - Beginning in Water Year 2015 the amount of the discretionary diversion is scheduled to be reduced to an annual average of 101 cfs

Project Goal

- Maximize the effectiveness of the use of the Instream Aeration Stations (IASs), Sidestream Elevated Pool Aeration (SEPA) Stations, and Discretionary Diversion



Project Phases

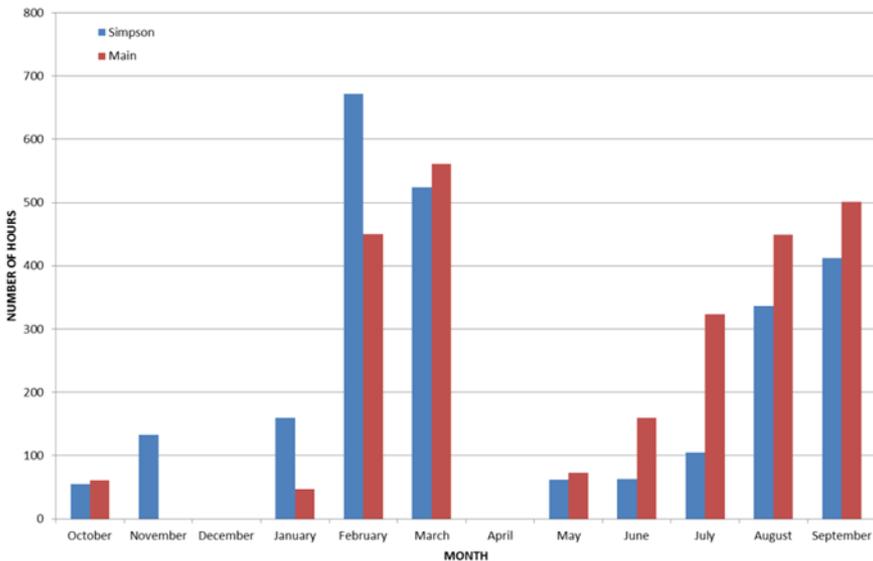
- 1) Determine if discretionary diversion could be changed at Wilmette to greatly improve compliance with DO standards on the North Shore Channel (NSC) without affecting compliance elsewhere in the CAWS.
- 2) Determine more optimal allocation of discretionary diversion and IAS and SEPA station operations to improve compliance with DO standards throughout the CAWS.

Project Phases

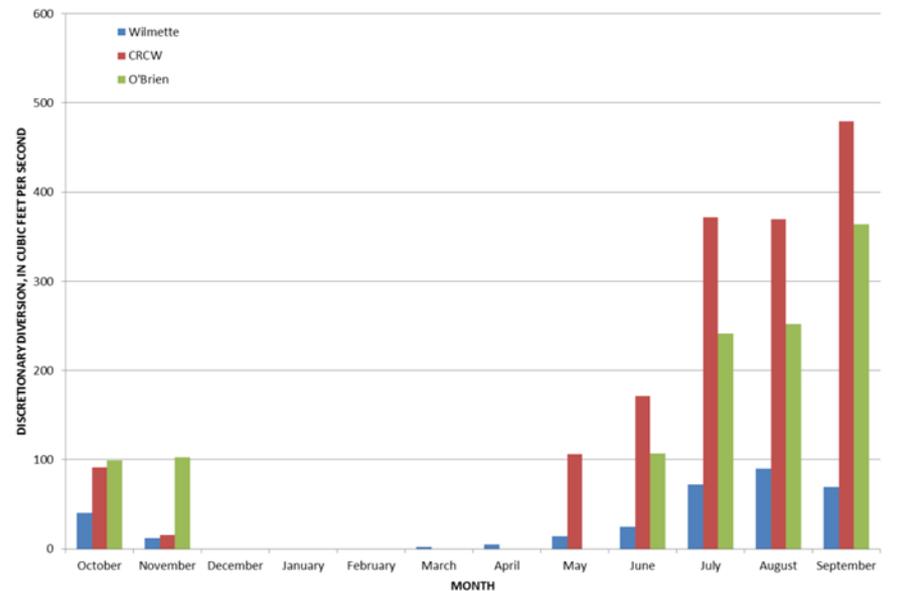
- 3) Consider the effectiveness of the Devon Avenue IAS and evaluate alternative locations for a new station that would be more effective than the Devon Avenue IAS.
- 4) Determine an implementable approach to more optimally use the available discretionary diversion.

Compliance with DO Standards vs. Discretionary Diversion Distribution

Number of Hours Not Meeting the IEPA Proposed DO Standards on the Upper North Shore Channel for Water Year 2001



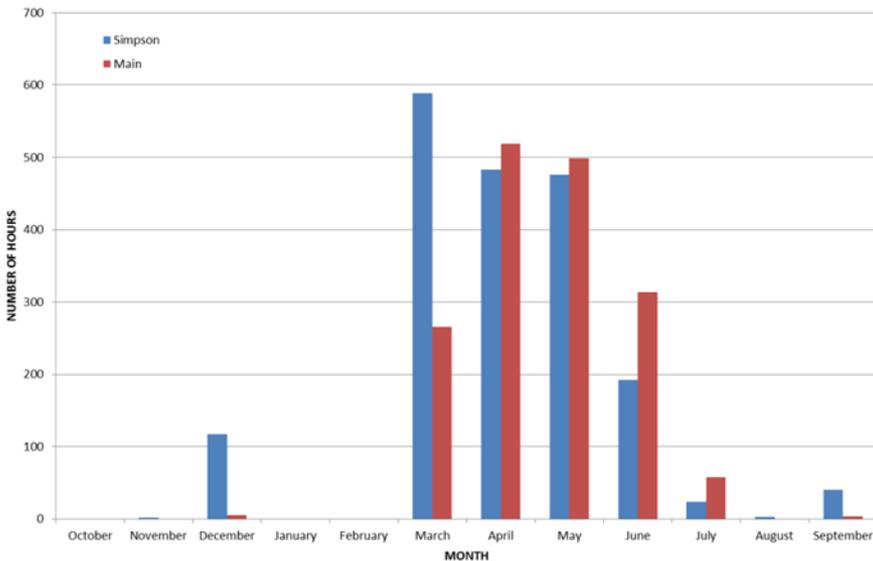
Monthly Discretionary Diversion in Water Year 2001



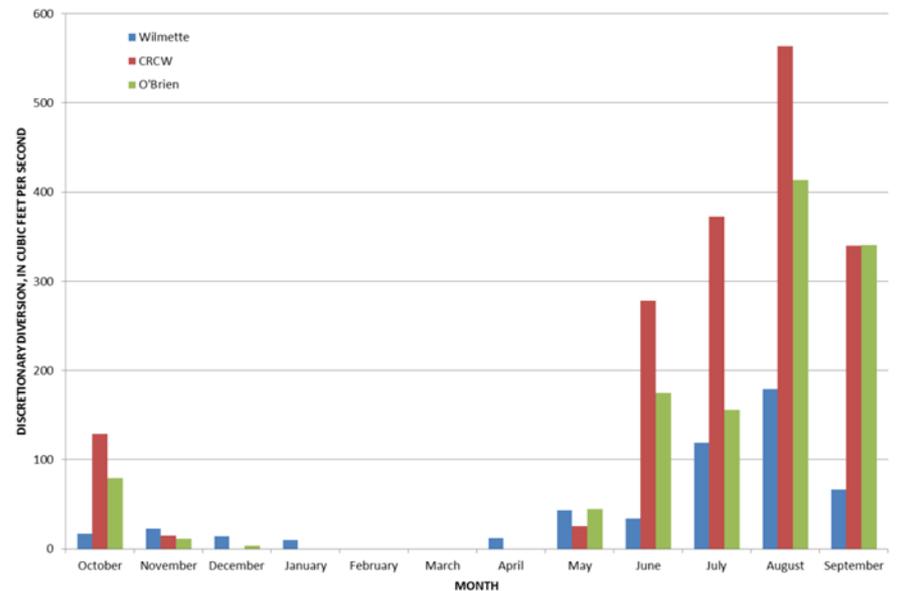
Overall Percentage of Compliance: Simpson Street = 71.2%, Main Street = 70.0%

Compliance with DO Standards vs. Discretionary Diversion Distribution

Number of Hours Not Meeting the IEPA Proposed DO Standards on the Upper North Shore Channel for Water Year 2003



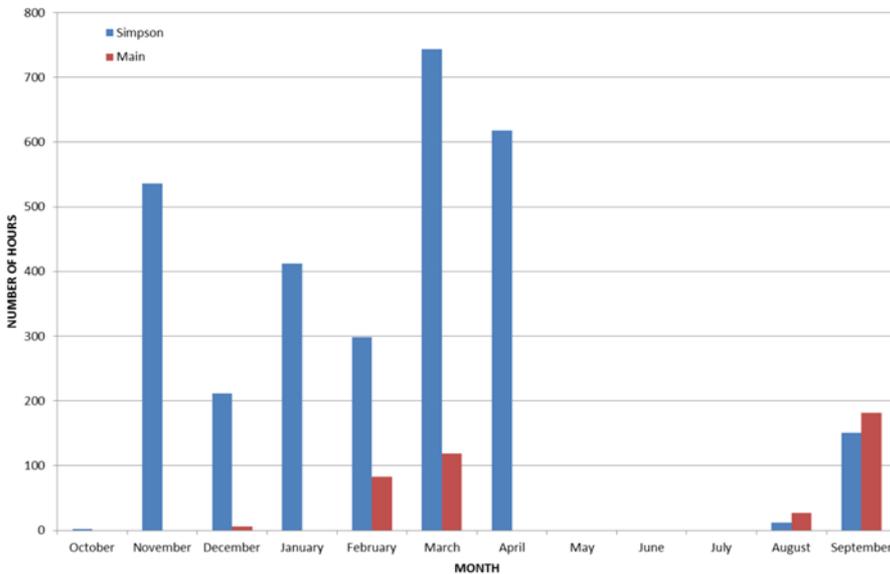
Monthly Discretionary Diversion in Water Year 2003



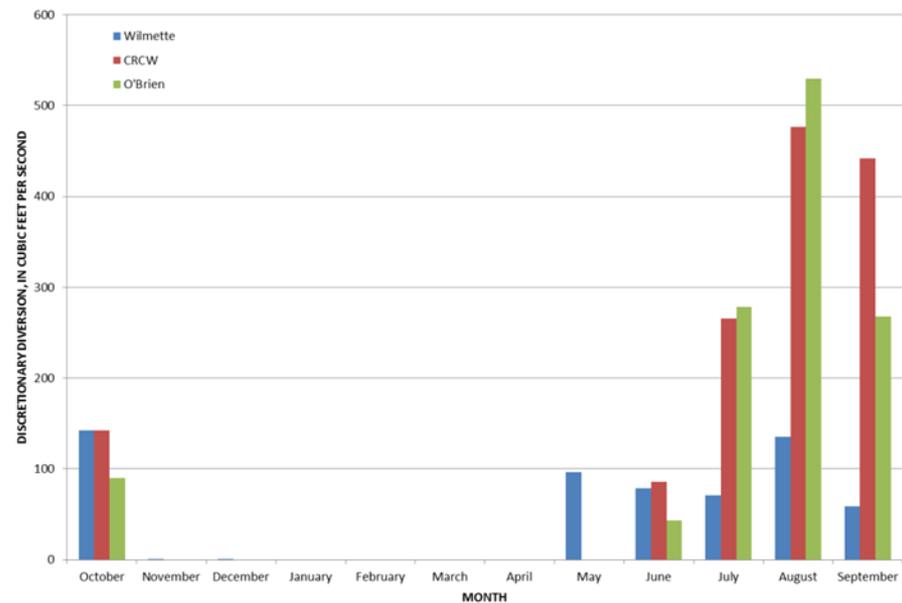
Overall Percentage of Compliance: Simpson Street = 78.0%, Main Street = 81.0%

Compliance with DO Standards vs. Discretionary Diversion Distribution

Number of Hours Not Meeting the IEPA Proposed DO Standards on the Upper North Shore Channel for Water Year 2008



Month Discretionary Diversion in Water Year 2008



Overall Percentage of Compliance: Simpson Street = 66.0%,
Main Street = 95.2%

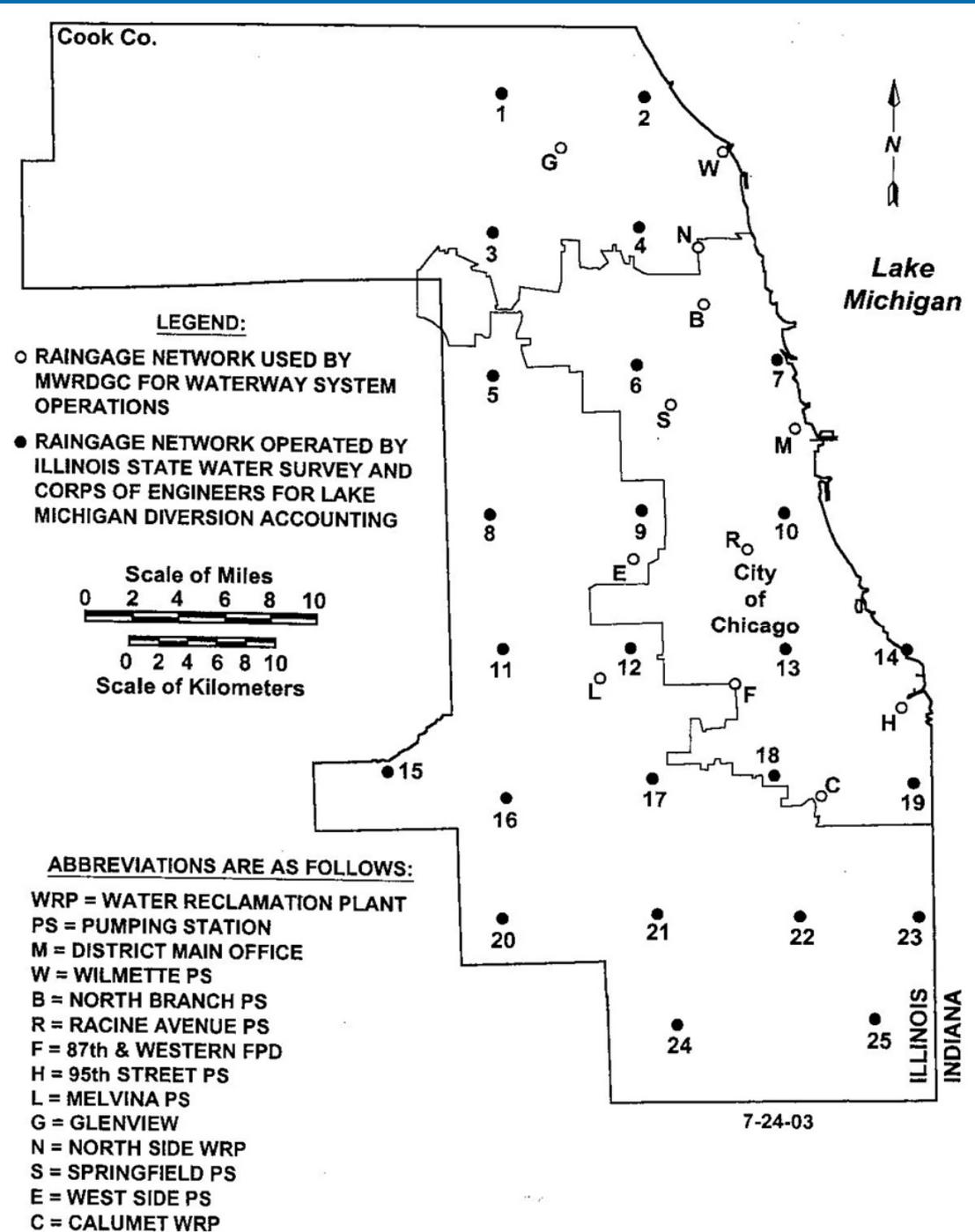
Phase I Goal

- Research by Marquette University has found that dilution via flow transfers within the CAWS is not an effective way to remediate the low DO concentrations resulting from CSOs
- Similarly, research by the MWRDGC has found that dilution via increased discretionary diversion is not an effective way to remediate the low DO concentrations resulting from CSOs
- **Goal: Increasing discretionary diversion from Lake Michigan at Wilmette to achieve full compliance with the IEPA proposed DO standards during dry weather and provision of some remediation of low DO concentrations during wet weather in the UNSC.**

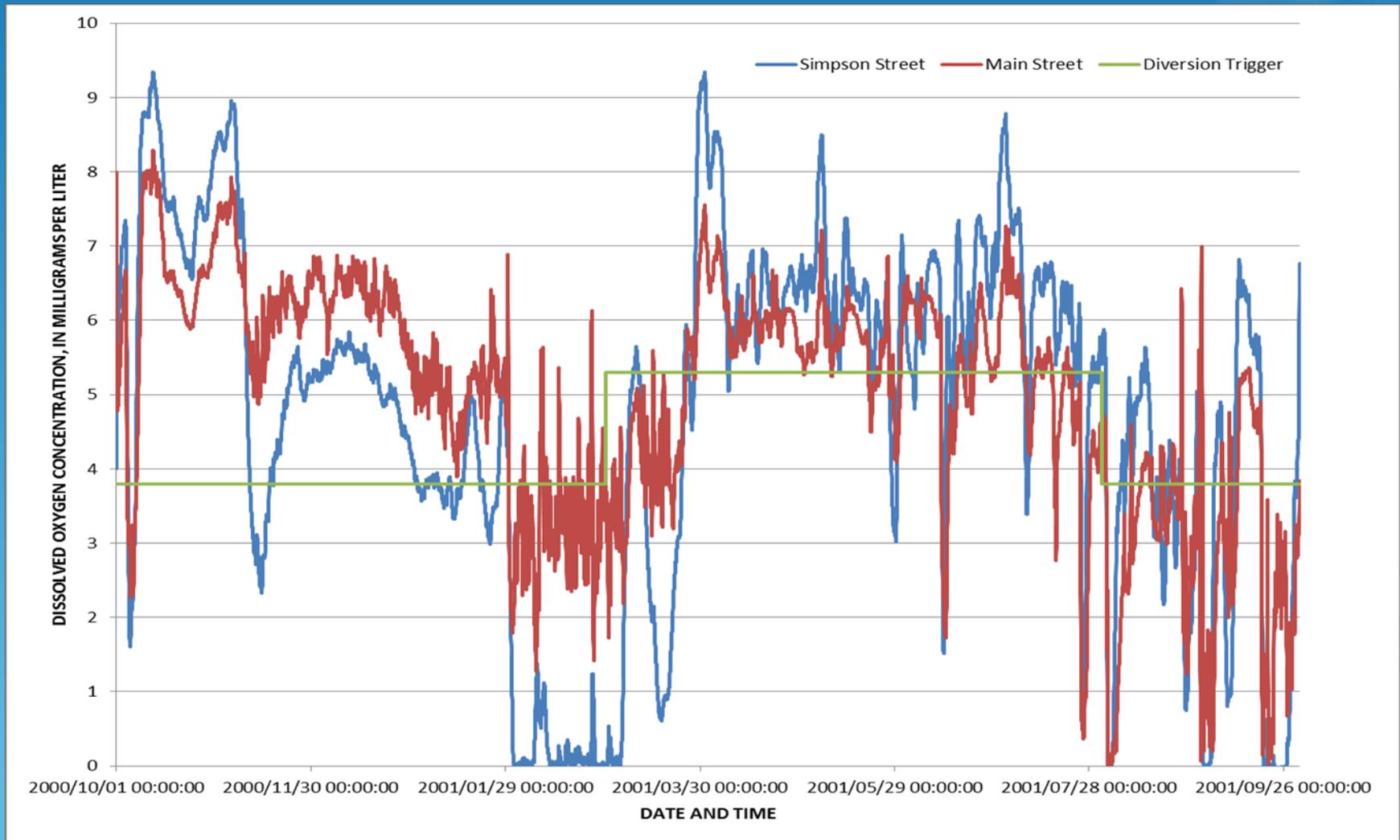
Wet vs. Dry Weather

- Research by the MWRDGC and Limnotech found that Dissolved Oxygen concentrations in the CAWS were adversely affected by wet weather for several days depending on the size of the storm.
 - Precipitation between 0.25 and 0.49 in. affects DO up to 2 days
 - Precipitation between 0.50 and 0.99 in. affects DO up to 4 days
 - Precipitation greater than or equal to 1.00 in. affects DO up to 6 days.

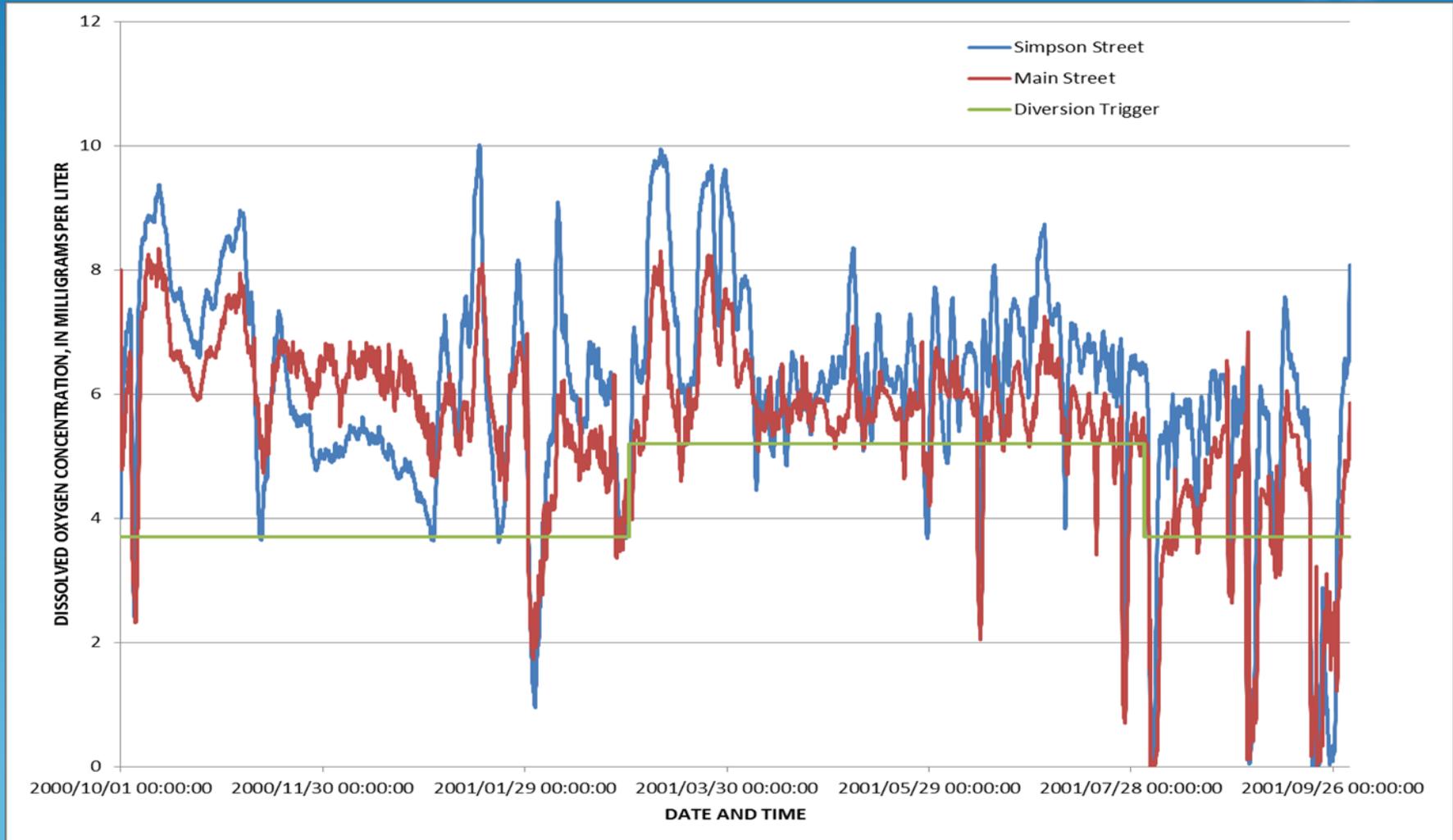
For the upper North Shore Channel, Limnotech used MWRDGC gages W and N to define wet periods. In this study, the average of ISWS gages 2 and 4 were used to define wet periods.



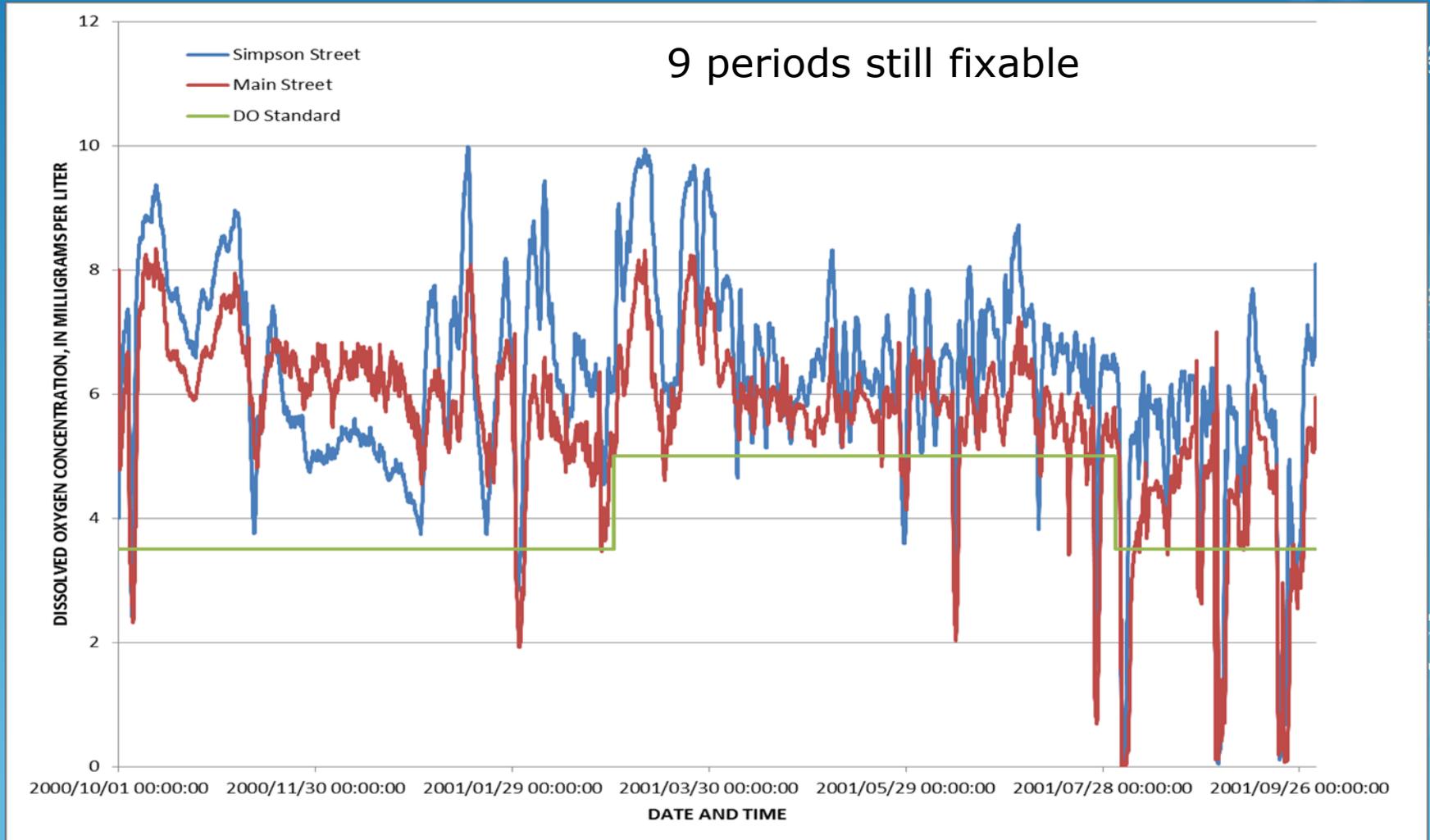
Identification of periods needing increased discretionary diversion at Wilmette—WY 2001



Identification of periods needing increased discretionary diversion at Wilmette—after 15 cfs increase



Identification of periods needing increased discretionary diversion at Wilmette—after 15 cfs increase twice



6 Simple Fixable Periods – WY 2001

- One period solved with a total increase in discretionary diversion of 40 cfs
- Two periods solved with a total increase in discretionary diversion of 50 cfs
- Three periods solved with a total increase in discretionary diversion of 60 cfs

1 Systematic Fixable Period – WY 2001

- Low DO concentrations on September 25-27 (dry period), require the increased diversion to begin on September 26th (wet period)

2 Complex Fixable Periods – WY 2001

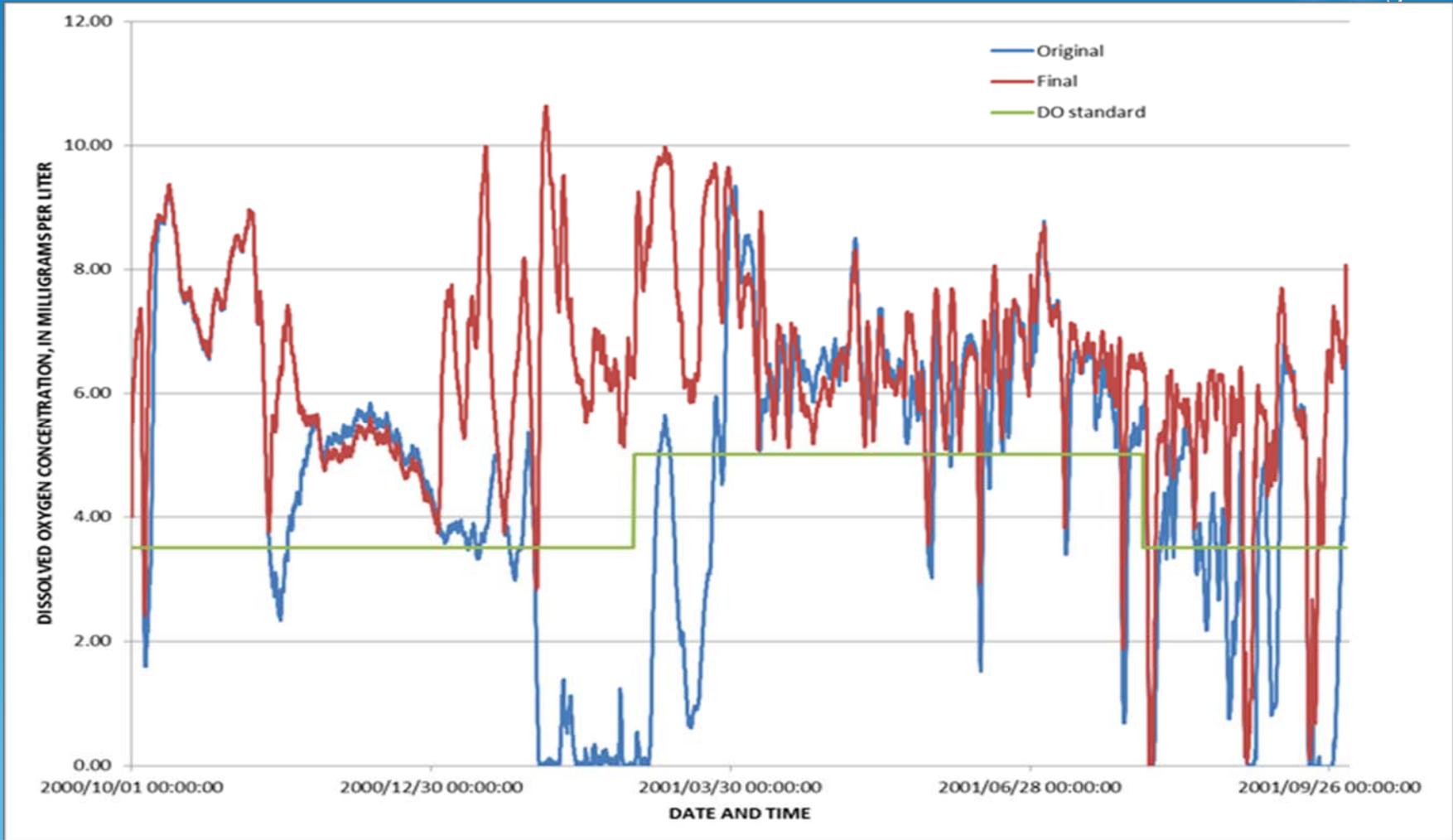
- For the period of 0:00 on August 8th to 9:00 on August 9th a total increased diversion of 60 cfs can bring this period into full compliance with the proposed DO standards, but this increased diversion needs to start 3 hours before the DO concentration drops below 3.6 mg/L.
- For the period of 8:00 on April 7th to 13:00 on April 8th a total increased diversion of 60 cfs can bring this period into full compliance with the proposed DO standards, but this increased diversion needs to start 6 hours before the DO concentration drops below 3.6 mg/L.

Number of Hours not in Compliance with IEPA Proposed DO Standards – WY 2001

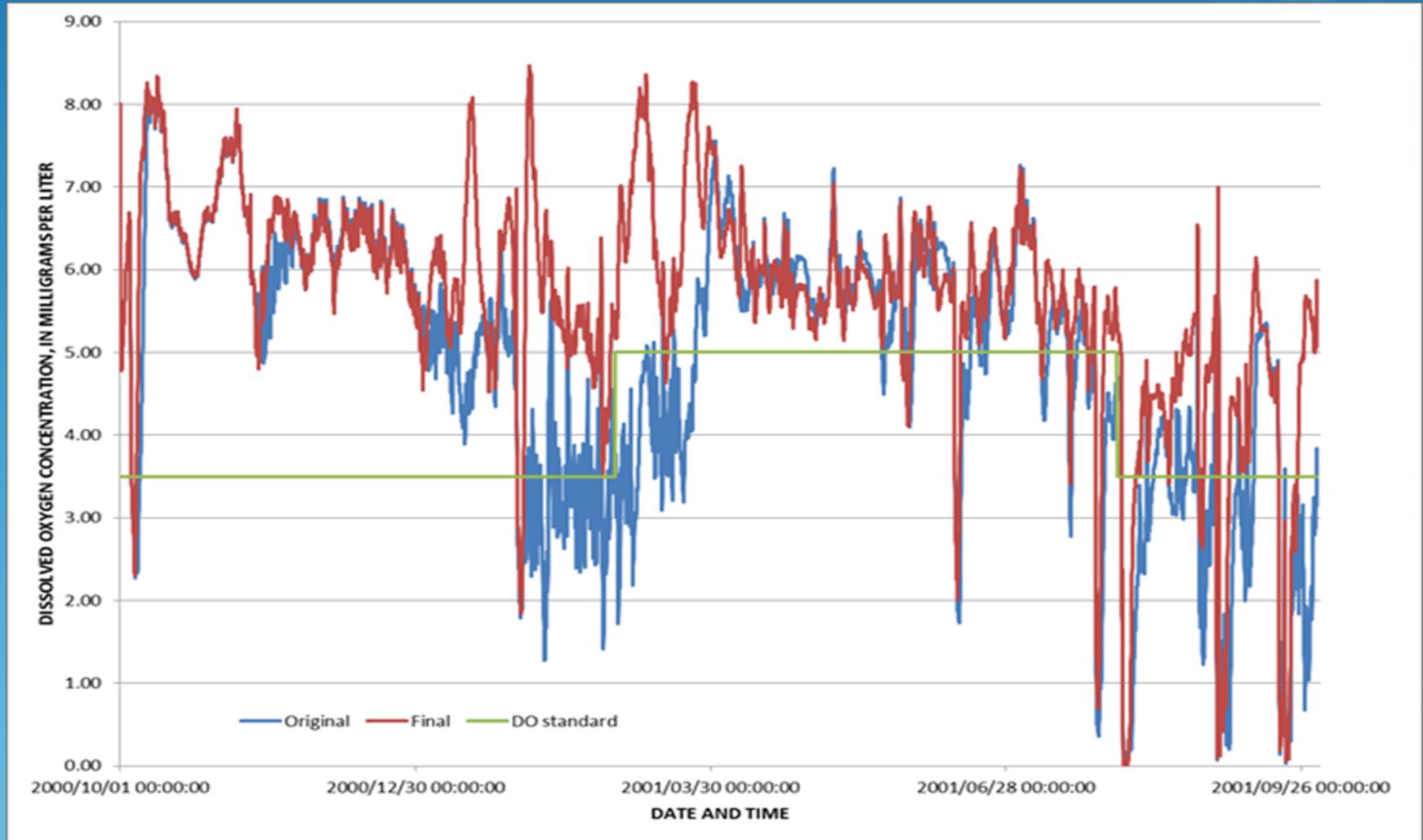
Month	Dry				Wet			
	Simpson Street		Main Street		Simpson Street		Main Street	
	Original	Final	Original	Final	Original	Final	Original	Final
October	0	0	0	0	55	18	61	35
November	25	0	0	0	108	0	0	0
December	0	0	0	0	0	0	0	0
January	139	5	24	24	21	18	23	22
February	456	0	325	0	216	0	125	0
March	404	0	457	0	120	0	104	23
April	0	0	0	0	0	0	0	0
May	5	0	37	0	57	40	36	59
June	13	0	73	0	50	27	87	46
July	0	0	41	0	105	49	282	127
August	25	0	92	0	311	78	357	157
September	129	0	205	0	283	130	296	212

Total Percentage Compliance with IEPA proposed DO standards:
 Simpson Street = 95.8%, Main Street = 92.0%

Simpson Street – WY 2001

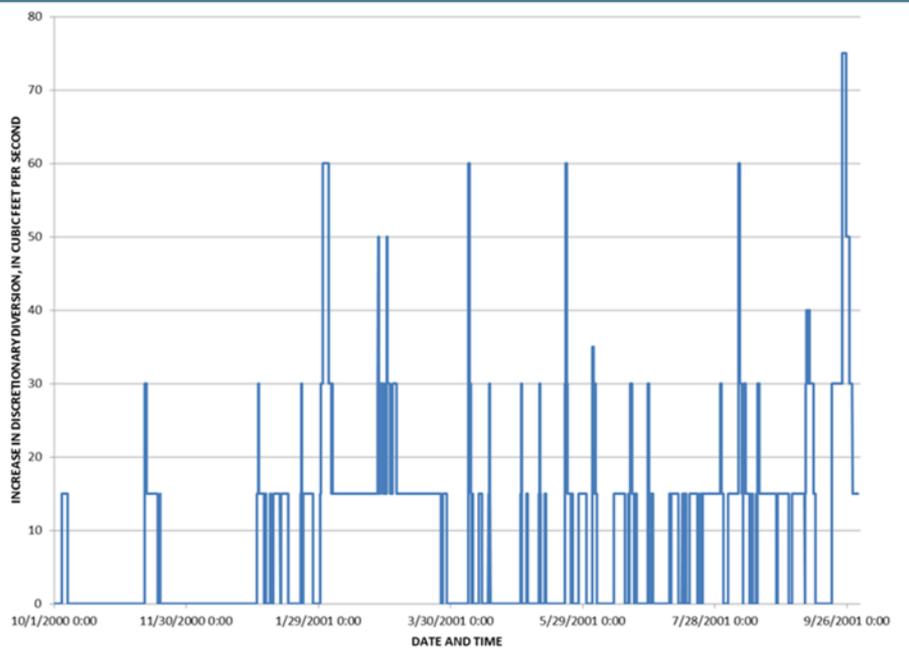


Main Street – WY 2001

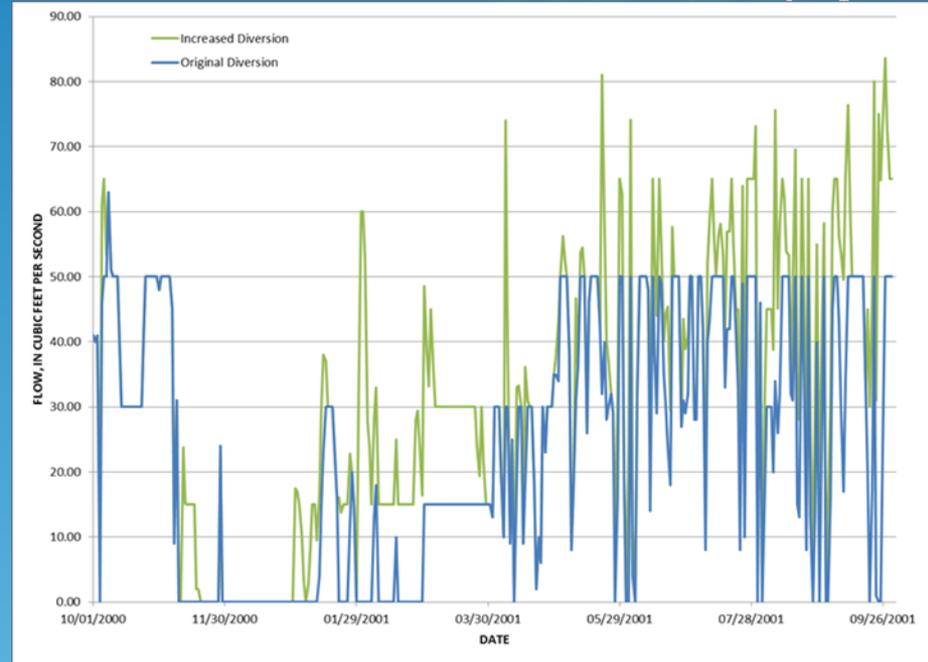


Increased Discretionary Diversion – WY 2001

Increased Diversion



Total Diversion



Increased Discretionary Diversion – WY 2001

- In total over the year the increase in the discretionary diversion from Lake Michigan at Wilmette amounts to 9.12 cfs or 3.38% of the total annual allowed discretionary diversion of 270 cfs.
- Applied over a 31 day period this amounts to 107.43 cfs.
- The average daily discretionary diversion for October 2000 at CRCW and O'Brien was 91.16 and 99.51 cfs, respectively. **This can be the source of the needed 107.43 cfs.**

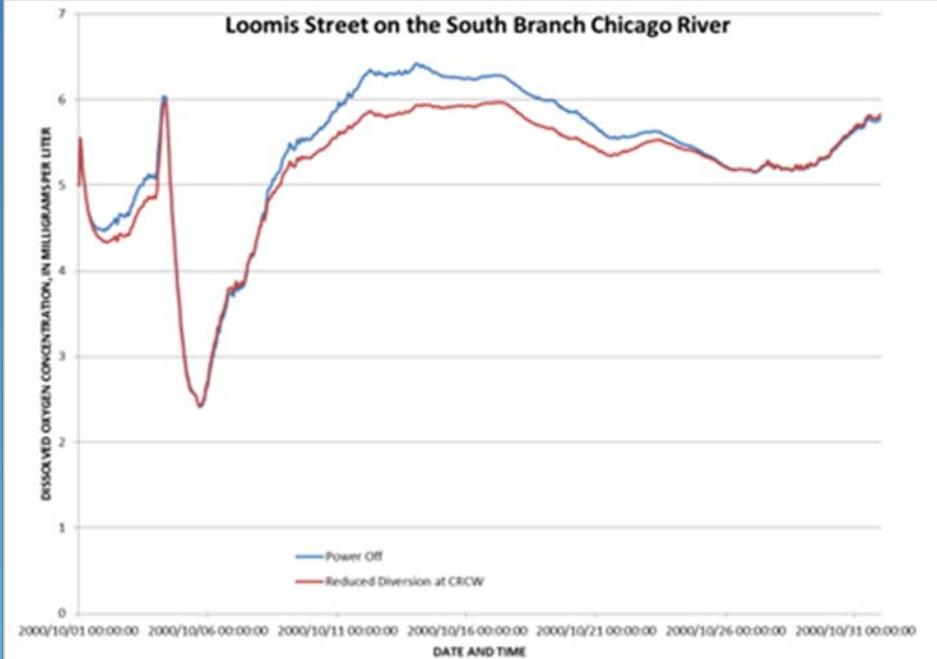
Reduced Discretionary Diversion at CRCW and O'Brien – WY 2001

- Initially, the discretionary diversion at CRCW was set to zero for the entire month of October.
- However, it was found that the period noncompliance during wet weather between October 4 and 7, 2000 increased from 41 to 66 hours at Loomis Street and from 32 to 38 hours at Cicero Avenue relative to the results for the actual discretionary diversion at CRCW for October 2000.
- Thus, it was necessary to restore the actual discretionary diversion on October 3-7, 2000, to achieve the same compliance at Loomis Street and slightly improved compliance (28 vs. 32 hours of noncompliance) at Cicero Avenue.

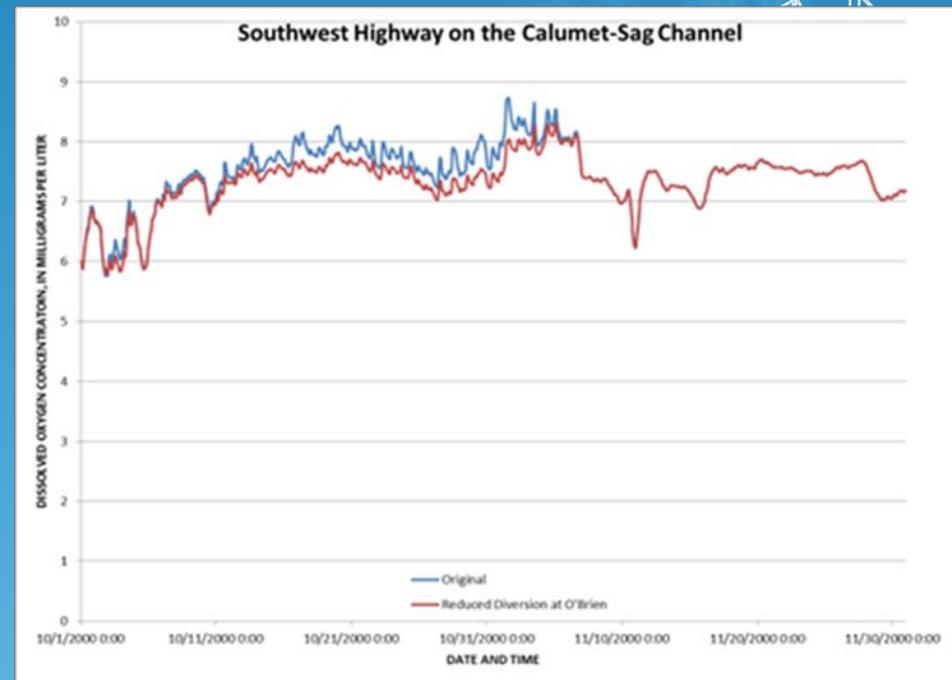
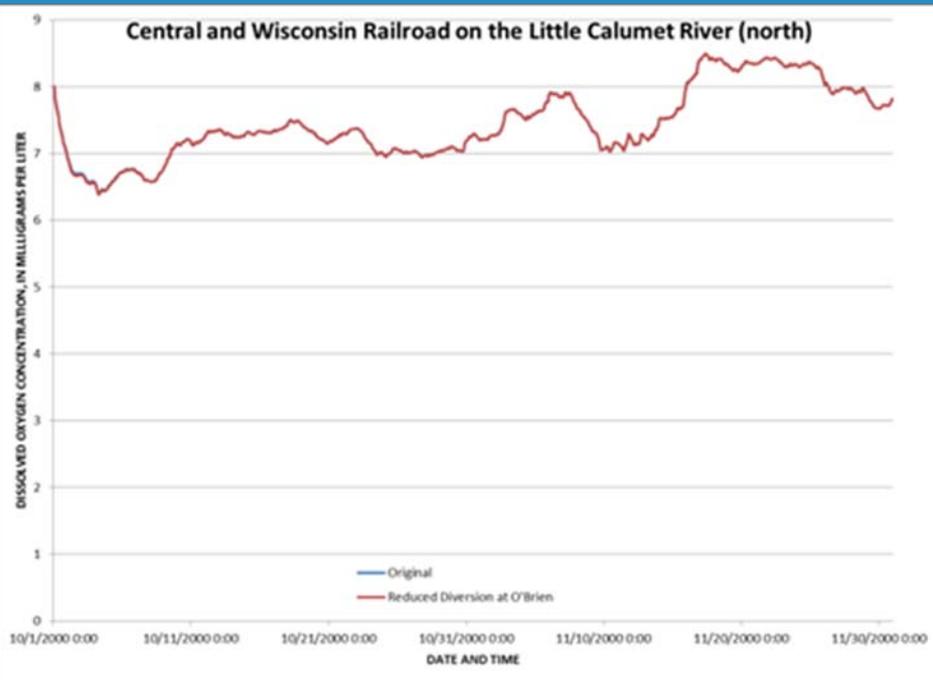
Reduced Discretionary Diversion at CRCW and O'Brien – WY 2001

- At CRCW the discretionary diversion for the month of October 2000, thus, was reduced by 71.55 cfs (from 91.16 to 19.61 cfs).
- Therefore, another 35.88 cfs had to be taken from the discretionary diversion at O'Brien to be withdrawn at Wilmette.
- The discretionary diversion at O'Brien was reduced 36.06% on all days in October to provide the needed flow increase at Wilmette.

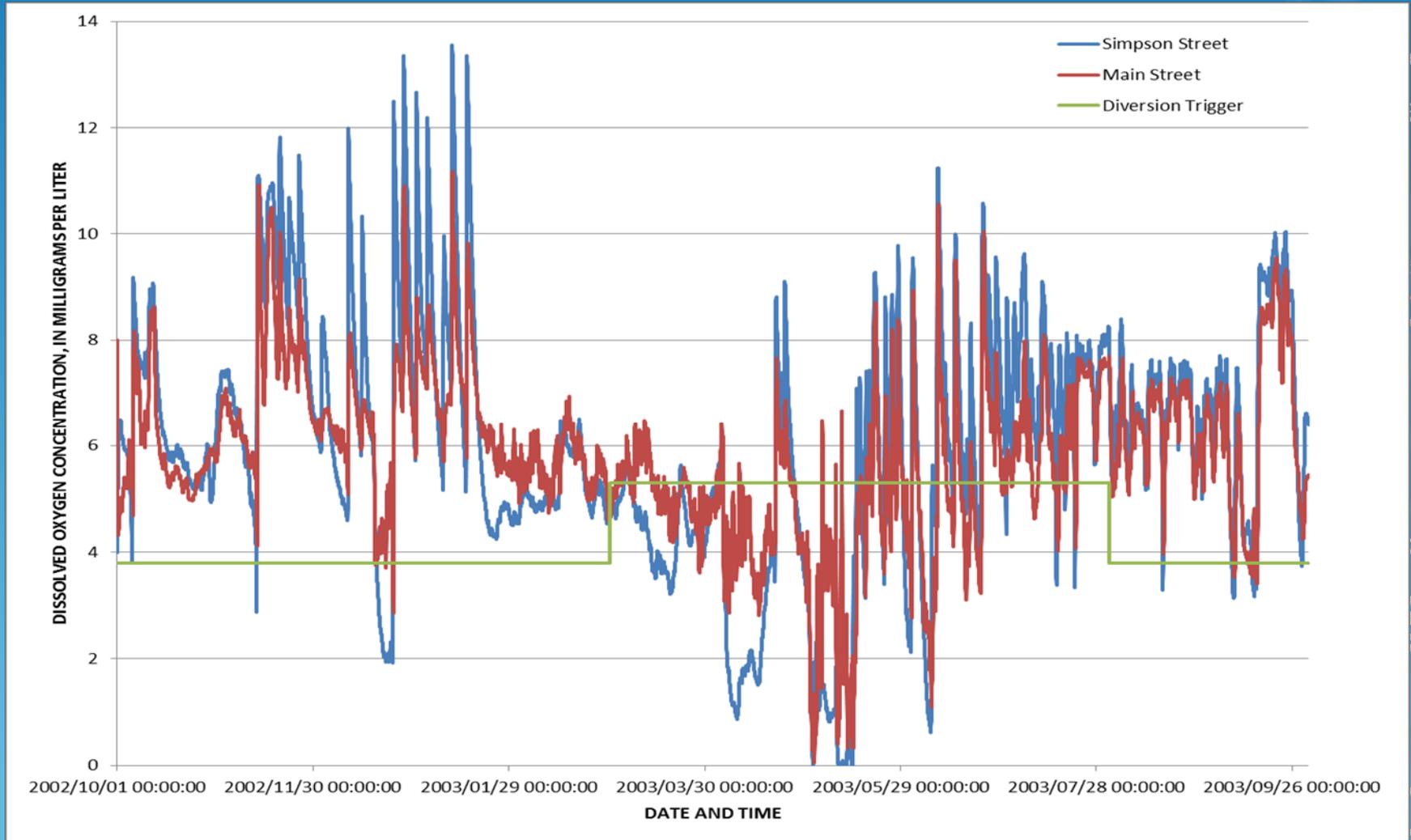
Effect of Reduction in discretionary diversion at points downstream from CRCW – WY 2001



Effect of Reduction in discretionary diversion at points downstream from O'Brien – WY 2001



Identification of periods needing increased discretionary diversion at Wilmette—WY 2003



1 Systematic Fixable Period – WY 2003

- For the period of 0:00 to 13:00 on March 1st, it was necessary to start the increased discretionary diversion 12 hours earlier, i.e. at 12:00 on February 28th.
- DO concentrations less than 5.0 mg/L were common throughout February, but were not a problem because the DO standard is 3.5 mg/L in February. However, on March 1st the DO standard changes to 5.0 mg/L.
- Thus, it was necessary to counteract the low DO concentrations on February 28th to achieve full compliance in March.

7 Complex Fixable Periods – WY 2003

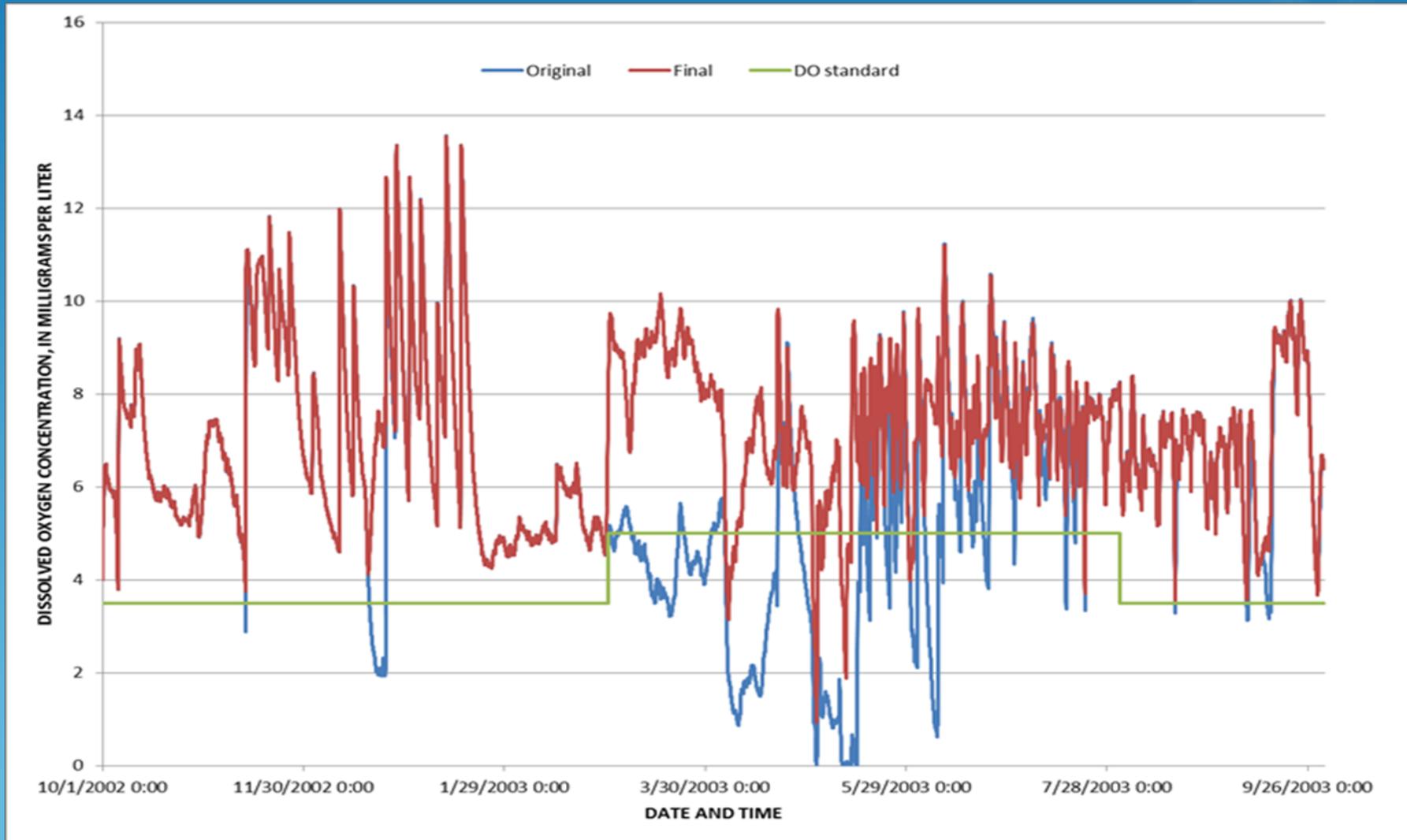
- These periods required starting the increased discretionary diversion **3, 5, or 6 hours before** the period of low DO concentrations could be detected from the simulation results

Number of Hours not in Compliance with IEPA Proposed DO Standards – WY 2003

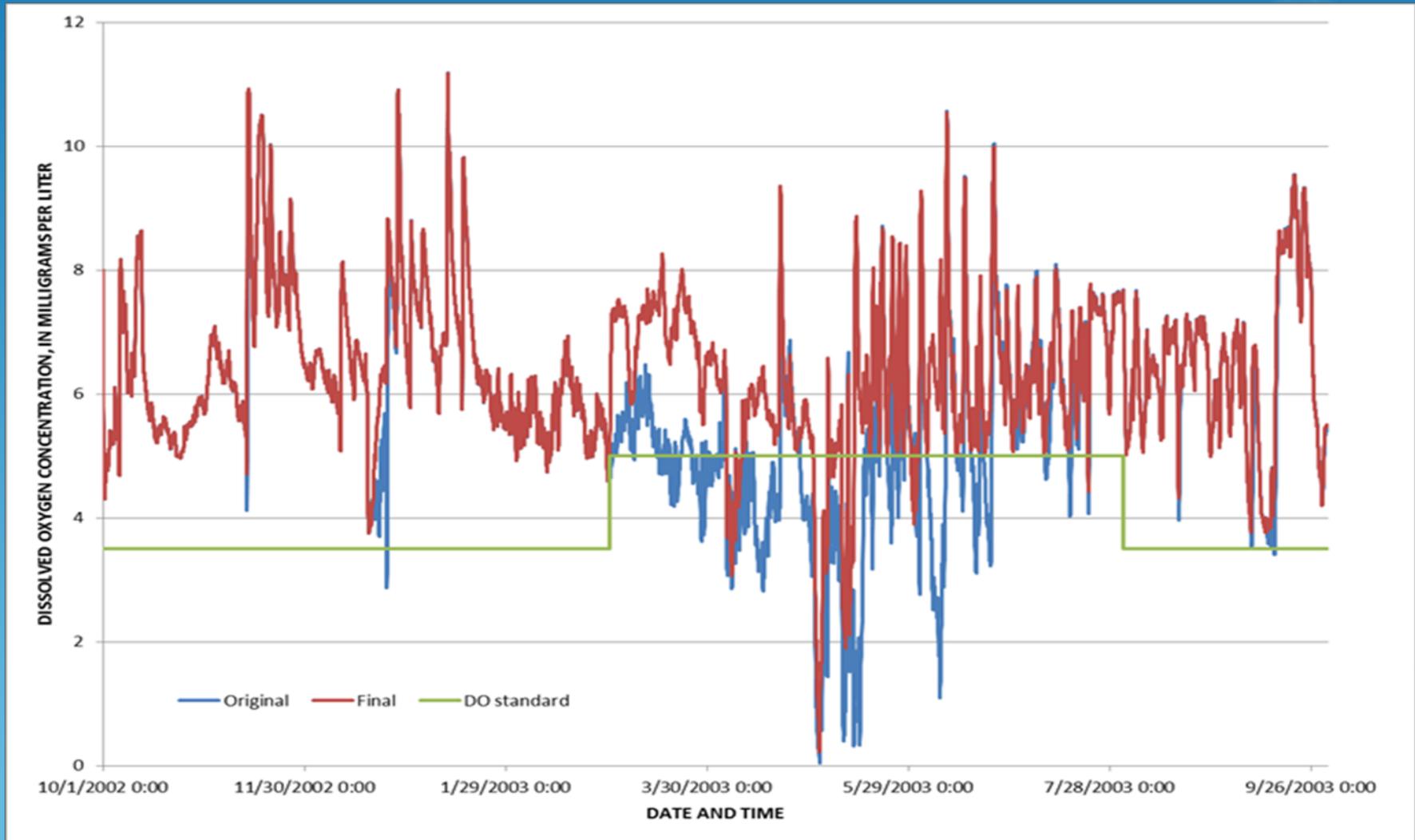
Month	Dry				Wet			
	Simpson Street		Main Street		Simpson Street		Main Street	
	Original	Final	Original	Final	Original	Final	Original	Final
October	0	0	0	0	0	0	0	0
November	2	0	0	0	0	0	0	0
December	14	0	5	0	103	0	0	0
January	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0
March	536	0	230	0	53	0	36	0
April	309	0	347	0	174	81	172	118
May	55	0	88	0	421	177	411	268
June	142	0	217	0	50	0	97	0
July	0	0	0	0	24	6	58	5
August	3	0	0	0	0	0	0	0
September	17	0	0	0	23	0	4	0

Total Percentage Compliance with IEPA proposed DO standards:
 Simpson Street = 97.0%, Main Street = 95.5%

Simpson Street – WY 2003



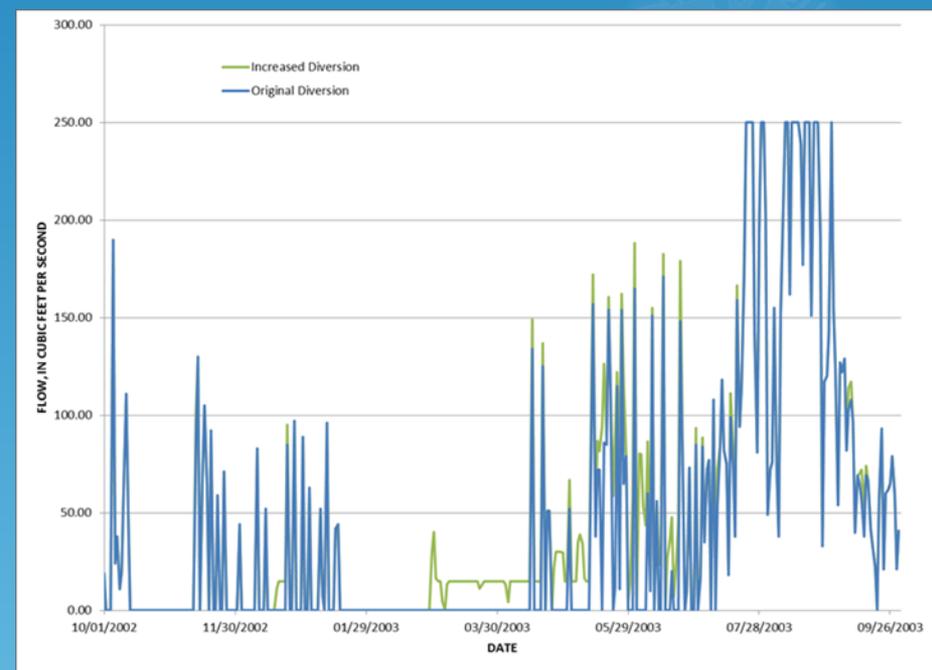
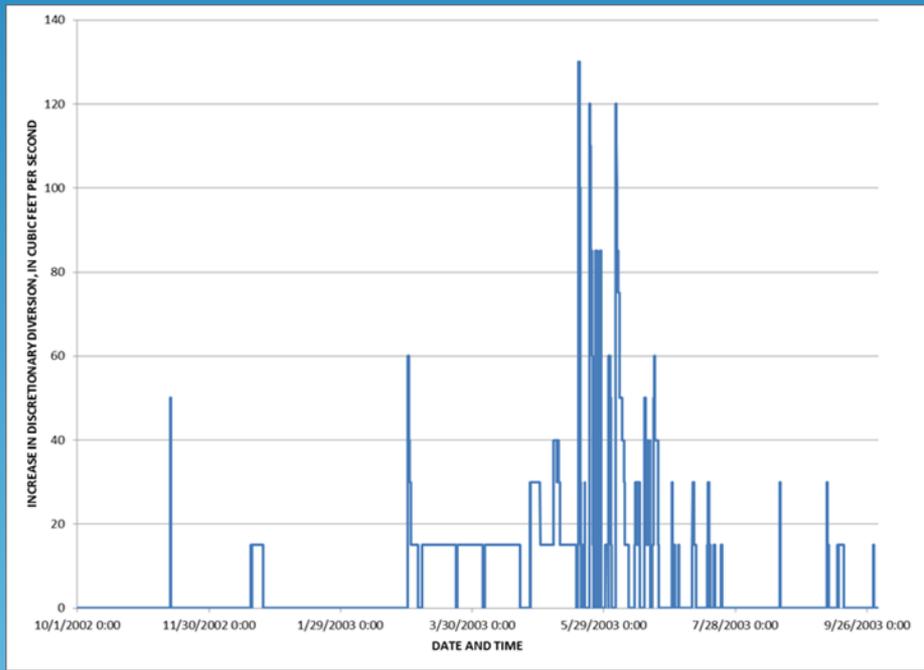
Main Street – WY 2003



Increased Discretionary Diversion – WY 2003

Increased Diversion

Total Diversion



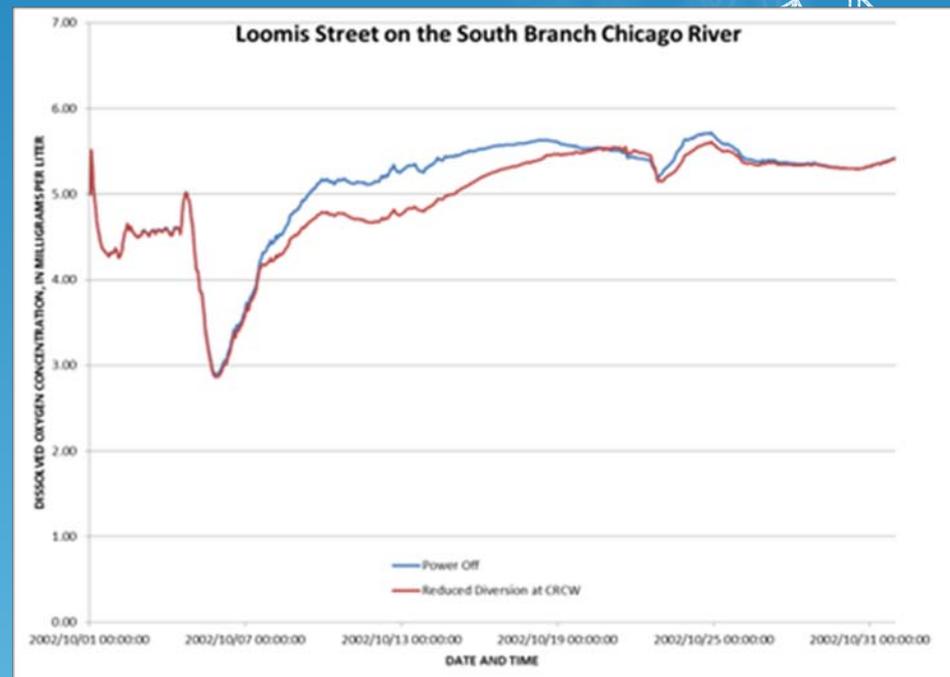
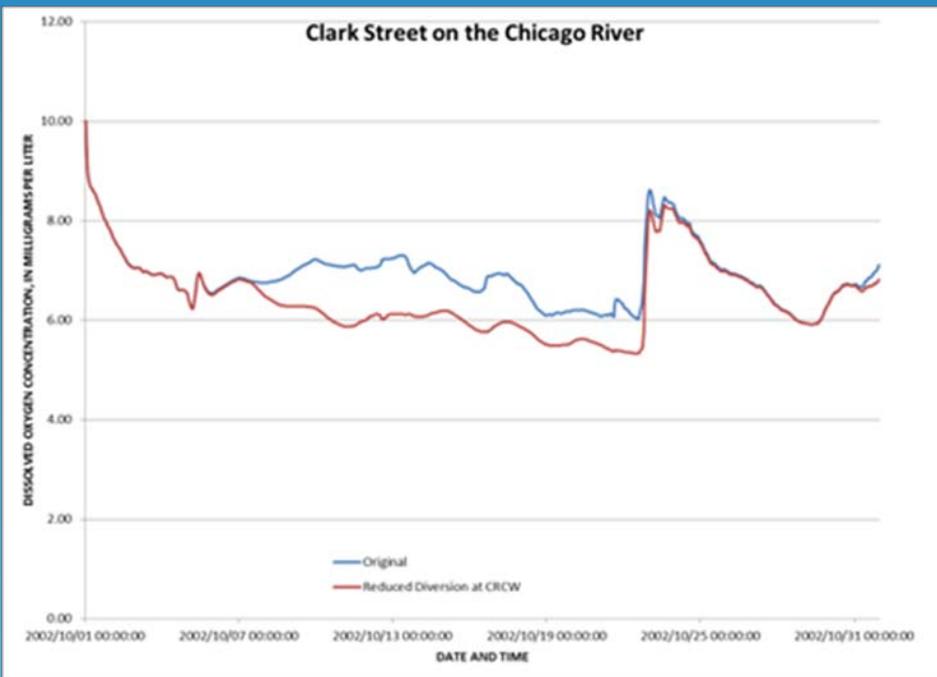
Increased Discretionary Diversion – WY 2003

- In total over the year the increase in the discretionary diversion from Lake Michigan at Wilmette amounts to 7.04 cfs or 2.61% of the total annual allowed discretionary diversion of 270 cfs.
- Applied over a 31 day period this amounts to 82.86 cfs.
- The average daily discretionary diversion for October 2002 at CRCW and O'Brien was 129.29 and 79.10 cfs, respectively. **This can be the source of the needed 82.86 cfs.**

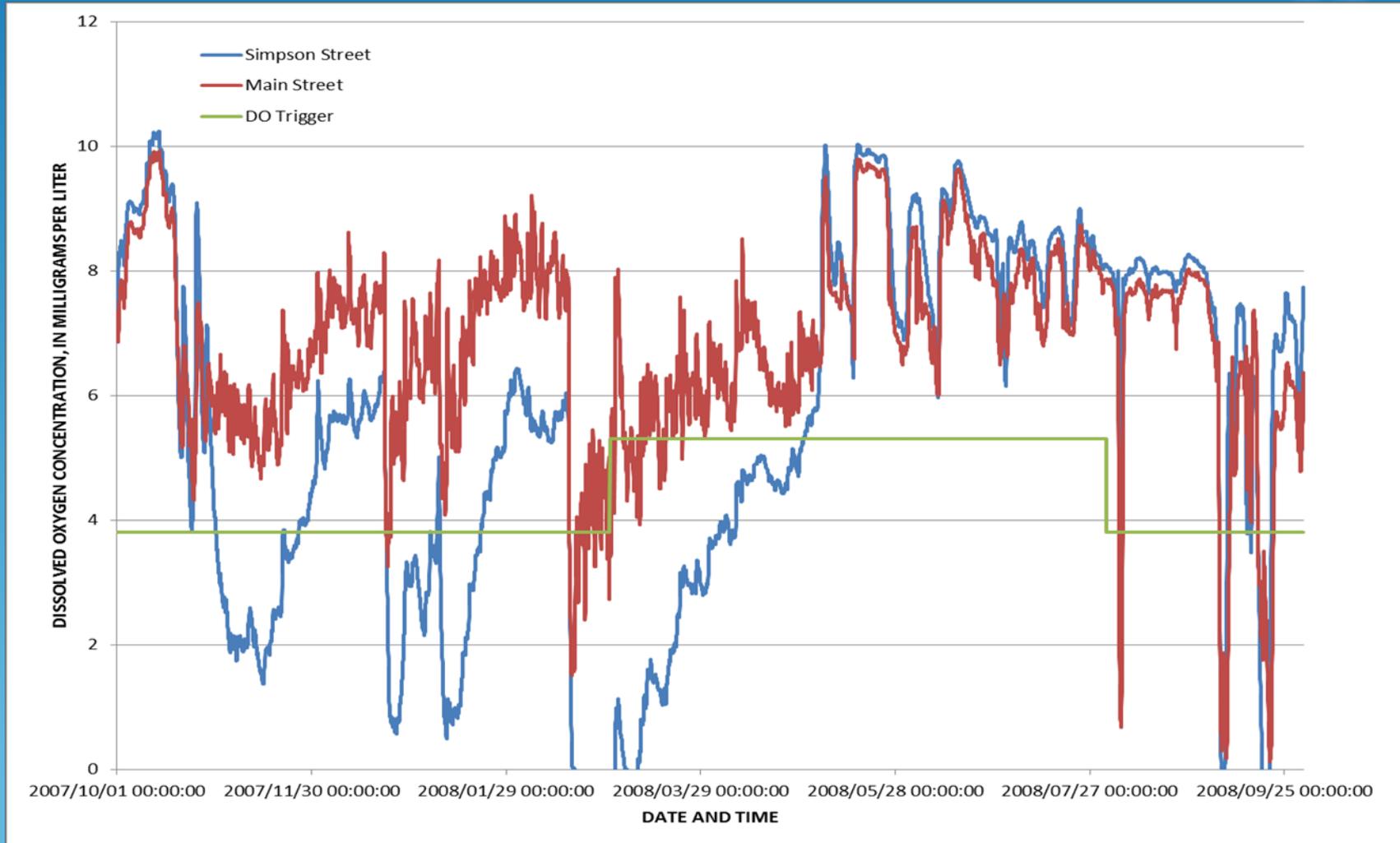
Reduced Discretionary Diversion at CRCW – WY 2003

- Initially, it was tried to apply the reduction uniformly (64.09% reduction, i.e. 82.86/129.29) across all days with discretionary diversion at CRCW in October 2002.
- This resulted in increases in non-compliance with the proposed DO standards during storm periods in October 2002 of 17, 4, and 5 hours at Loomis Street, Cicero Avenue, and Lockport, respectively.
- These non-complying storm periods stretched from 0:00 on October 3rd to 11:00 on October 7th. Thus, the discretionary diversion for 0:00 on October 1st to 12:00 on October 7th was restored.
- A 77.19% reduction in discretionary diversion was applied to the remainder of October.

Effect of Reduction in discretionary diversion at points downstream from CRCW – WY 2003



Identification of periods needing increased discretionary diversion at Wilmette—WY 2008



2 Systematic Fixable Period – WY 2008

- For the period 0:00-10:00 on March 1st, it was necessary to start the increased discretionary diversion 12 hours earlier, i.e. at 12:00 on February 29th as was done to remediate low DO concentrations on March 1, 2003.
- For the dry weather period of 0:00-22:00 on September 20th the low DO concentrations are a product of the September 4-19 storm period. Thus, in order to meet the DO standard throughout the dry period (as per the goals of this study), the further increase in discretionary diversion from the initial 15 cfs that started at 21:00 on the 16th needs to begin 24 hours earlier (i.e. 0:00 on September 19th, as was done for September 24, 2001).

1 Complex Fixable Periods – WY 2008

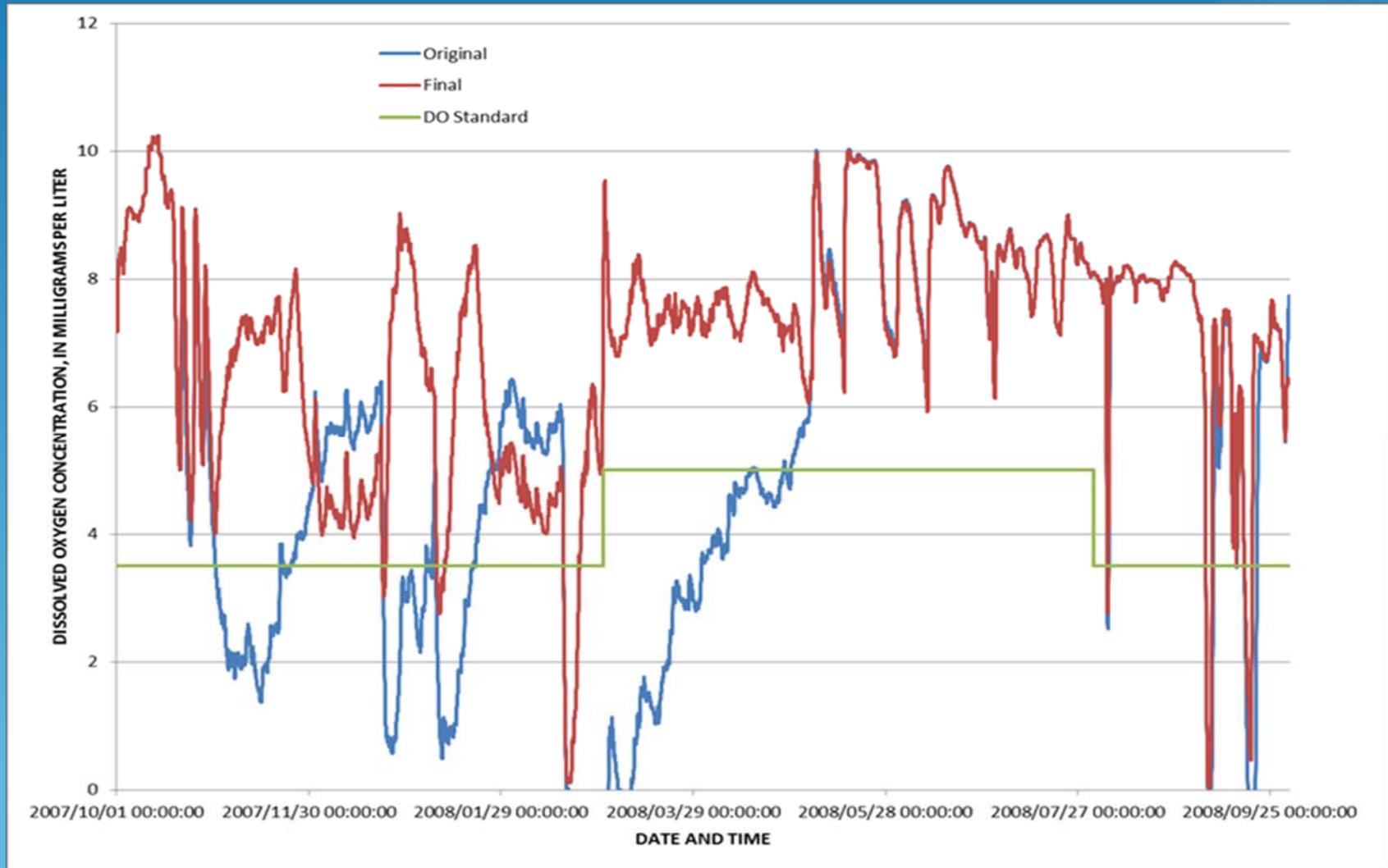
- The period of 22:00 on December 22nd to 6:00 on December 25th was a combination of dry (22)-wet (23-24)-dry (25) days. Applying 25 cfs to this entire period brought all hours on the 25th into compliance with the proposed DO standard.
- However, to achieve compliance on the 22nd it was necessary to begin the increased discretionary diversion **6 hours before** (i.e. 16:00) the times with low DO concentrations.

Number of Hours not in Compliance with IEPA Proposed DO Standards – WY 2008

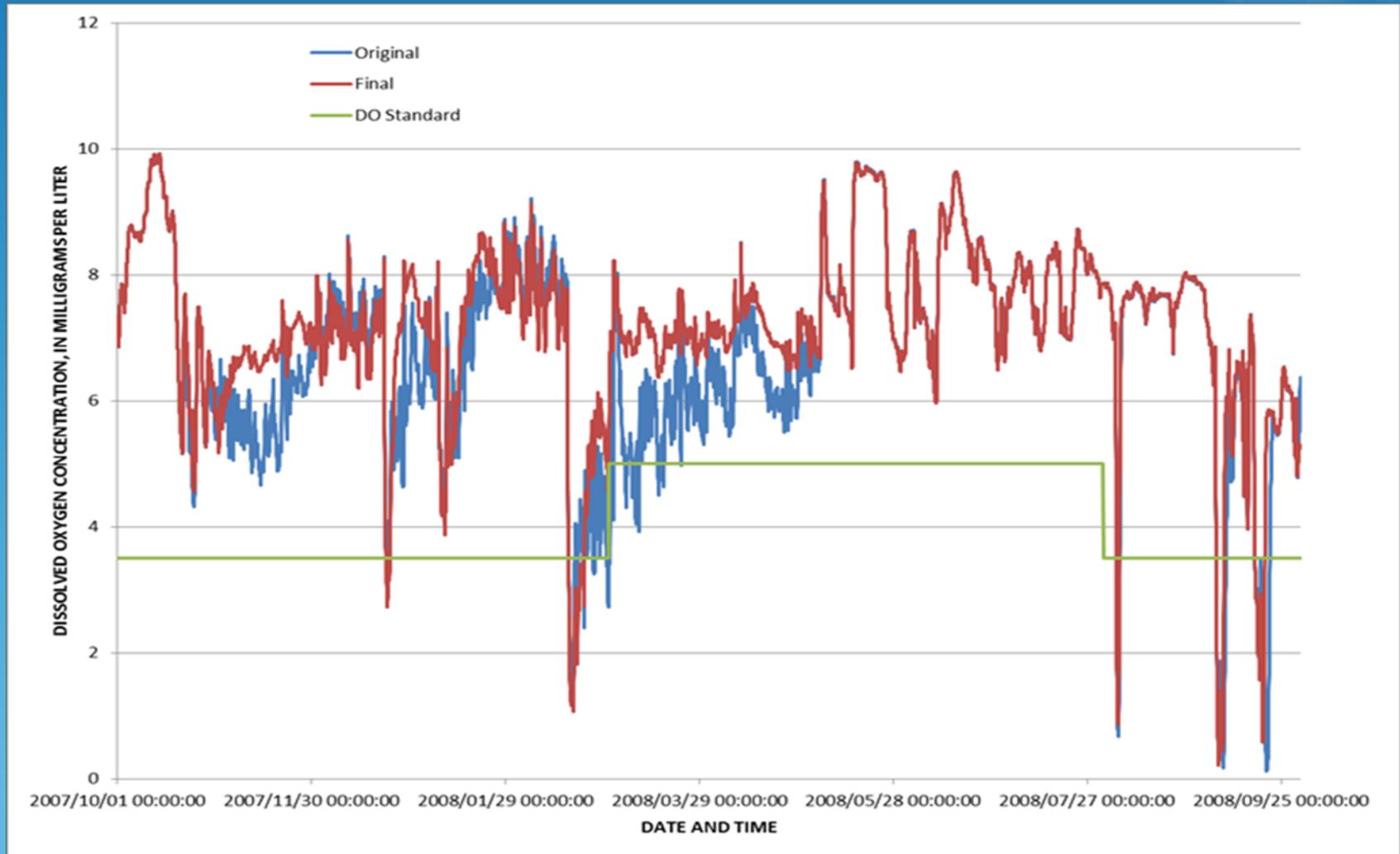
Month	Dry				Wet			
	Simpson Street		Main Street		Simpson Street		Main Street	
	Original	Final	Original	Final	Original	Final	Original	Final
October	2	0	0	0	0	0	0	0
November	480	0	0	0	56	0	0	0
December	0	0	0	0	212	25	6	33
January	308	0	0	0	104	56	0	0
February	96	0	5	0	203	119	78	120
March	480	0	97	0	264	0	22	0
April	388	0	0	0	230	0	0	0
May	0	0	0	0	0	0	0	0
June	0	0	0	0	0	0	0	0
July	0	0	0	0	0	0	0	0
August	0	0	0	0	12	9	27	24
September	23	0	37	0	128	104	145	131

Total Percentage Compliance with IEPA proposed DO standards: Simpson Street = 96.4%, Main Street = 96.5%

Simpson Street – WY 2008



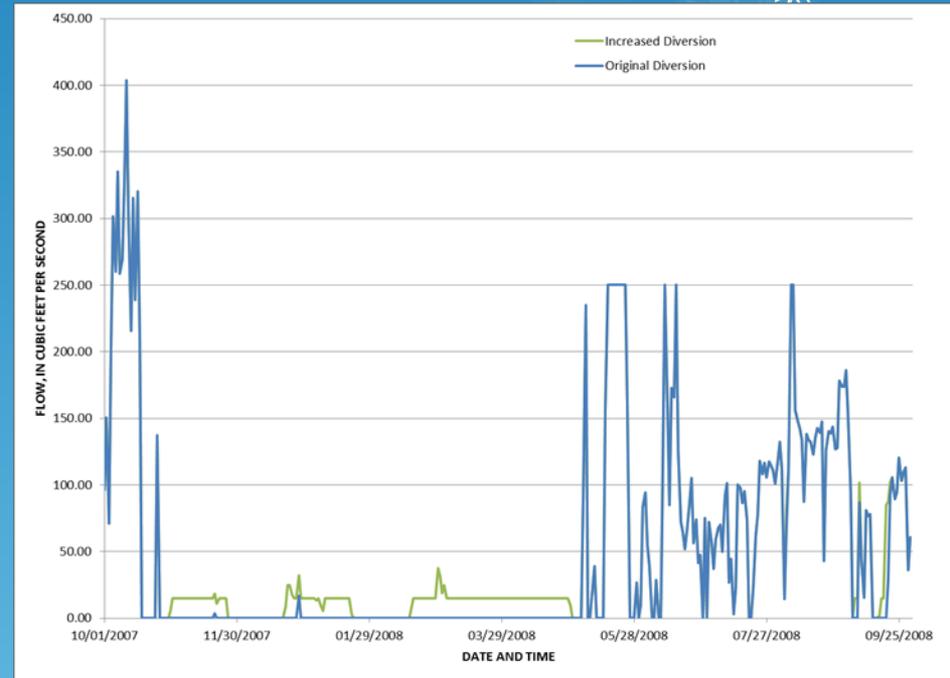
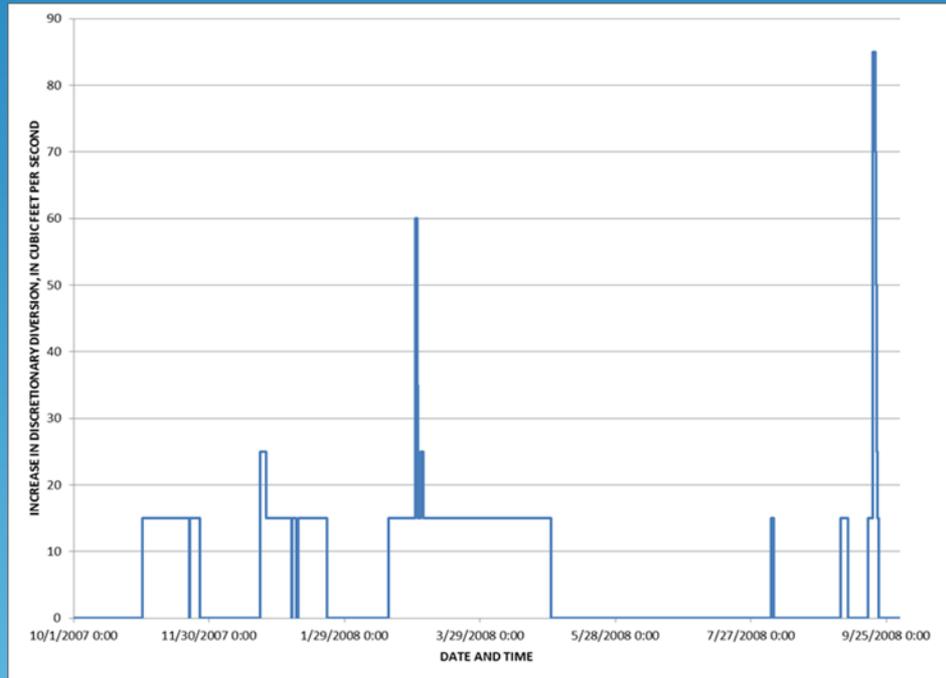
Main Street – WY 2008



Increased Discretionary Diversion

Increased Diversion

Total Diversion



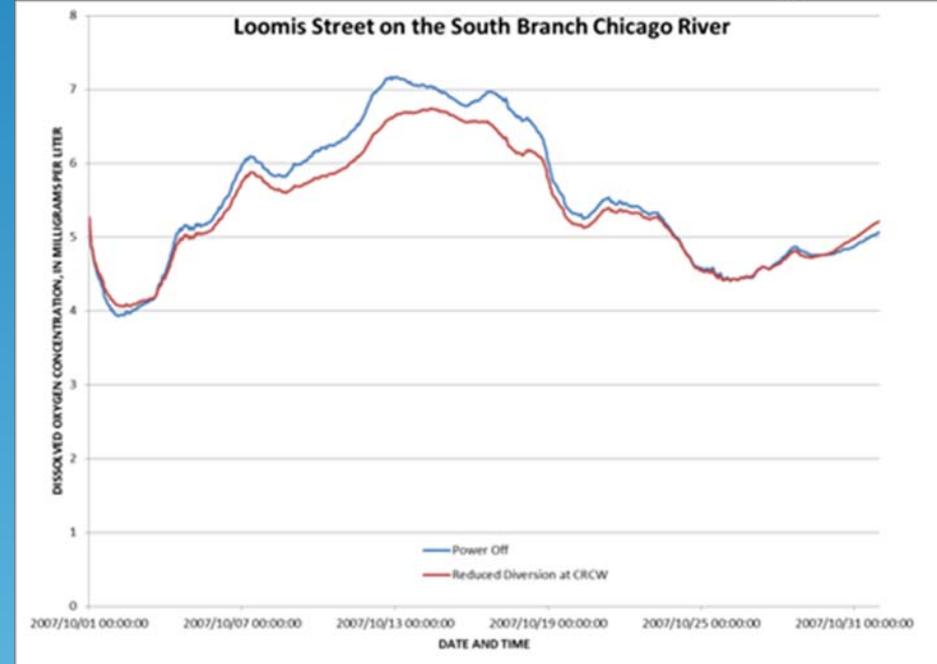
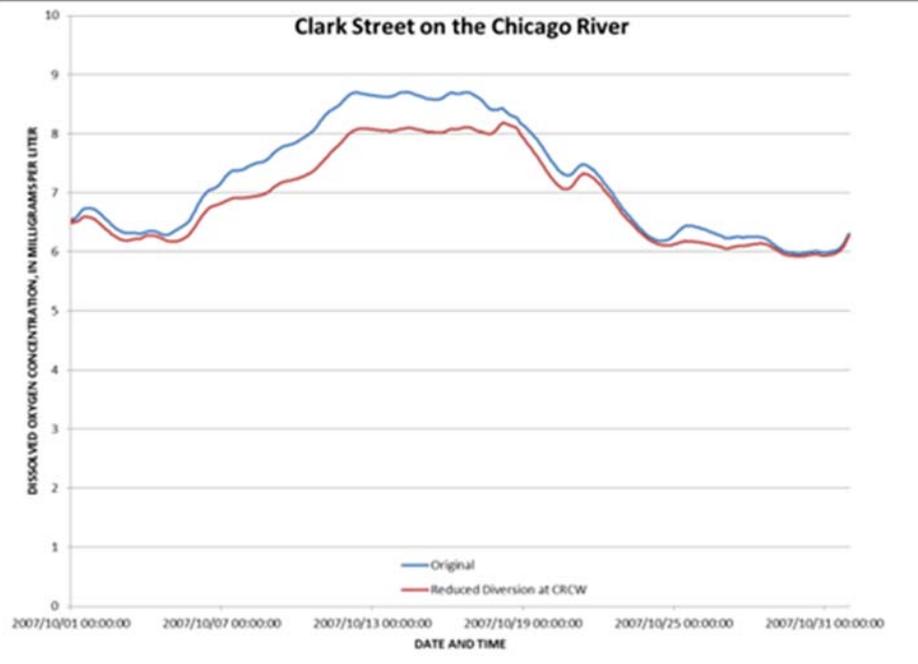
Increased Discretionary Diversion – WY 2008

- In total over the year the increase in the discretionary diversion from Lake Michigan at Wilmette amounts to 6.06 cfs or 2.24% of the total annual allowed discretionary diversion of 270 cfs.
- Applied over a 31 day period this amounts to 71.40 cfs.
- The average daily discretionary diversion for October 2007 at CRCW and O'Brien was 142.61 and 89.86 cfs, respectively. **This can be the source of the needed 71.40 cfs.**

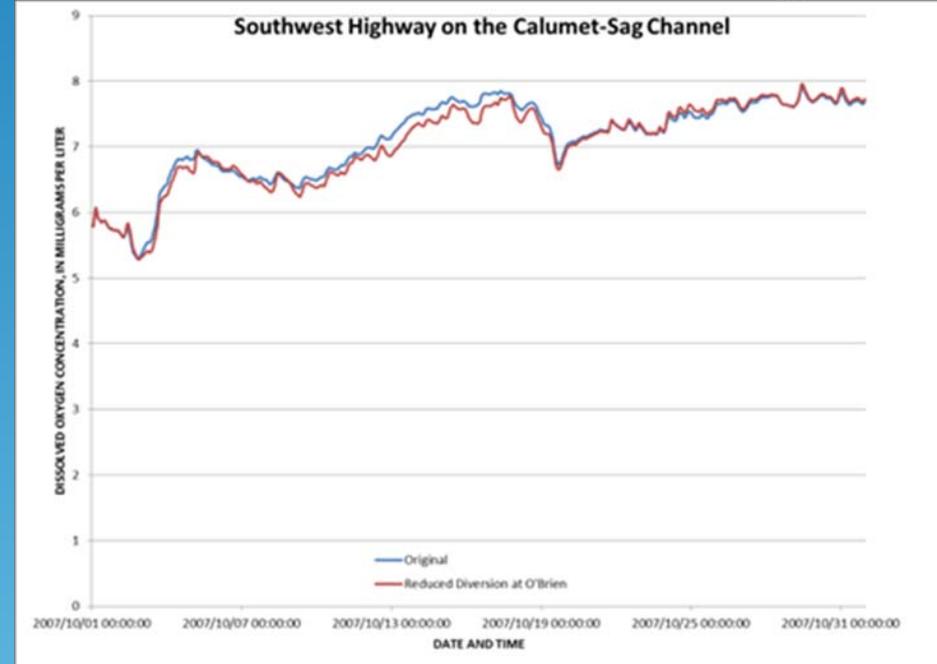
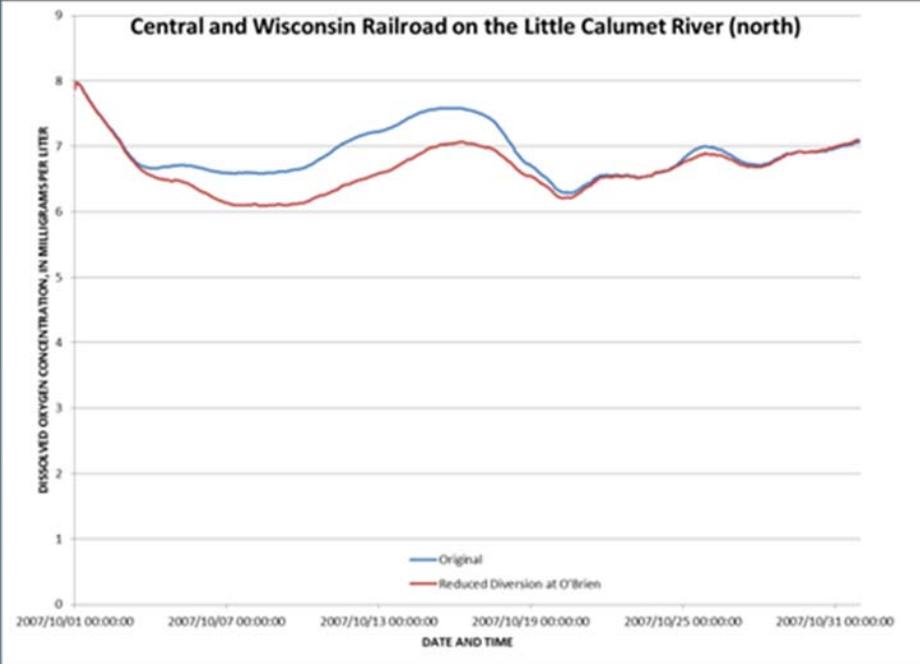
Reduced Discretionary Diversion at CRCW or O'Brien– WY 2008

- At CRCW the reduction was applied uniformly (50.07% reduction, i.e. 71.40/142.61) across all days with discretionary diversion in October 2007.
- At O'Brien Lock and Dam the reduction was applied uniformly (79.46%, i.e. 71.40/89.86) across all days with discretionary diversion in October 2007.

Effect of Reduction in discretionary diversion at points downstream from CRCW – WY 2008



Effect of Reduction in discretionary diversion at points downstream from O'Brien – WY 2008



Phase I – Summary

- Discretionary diversion can be shifted from CRCW and/or O'Brien in October 2000, 2002, or 2007 to Wilmette at various times throughout WY 2001, 2003, or 2008, respectively, so that full compliance with the IEPA proposed DO standards during dry weather and greatly increased compliance during wet weather could be achieved on the UNSC without decreasing compliance anywhere else in the CAWS.
- Overall, the **compliance over the entire year** with the proposed DO standards **ranged from 95.8 to 97.0% at Simpson Street and from 92.0 to 96.5% at Main Street** for the reallocations determined in this study.

Phase I – Summary

- These reallocations are not the optimal utilization of discretionary diversion throughout the CAWS just major improvements in compliance along the UNSC, and an improvement in compliance at many other points downstream of the UNSC.
- These cases illustrate that the MWRDGC can substantially improve compliance with the proposed DO standards just by making better use of the allowable discretionary diversion from Lake Michigan.

Phase II – Goal

- Redistribute the discretionary diversion in space and time at Wilmette, CRCW, and O'Brien to achieve full compliance with the IEPA proposed DO standards in dry weather and improved compliance in wet weather.
- Change operations of the IASs and SEPA stations to supplement the changes in discretionary diversion to achieve full compliance with the IEPA proposed DO standards in dry weather and improved compliance in wet weather.

Travel Times in the CAWS

Location	Waterway	Travel Time (hr)
Simpson Street	North Shore Channel	11.1
Main Street	North Shore Channel	22.2
Addison Street	North Branch Chicago River	38.5
Fullerton Avenue	North Branch Chicago River	43.7
Division Street	North Branch Chicago River	58.5
Kinzie Street	North Branch Chicago River	71.7
Wolf Point	North Branch Chicago River	75.8

Average Travel Time for July 1 to August 31, 2003

Travel Times in the CAWS



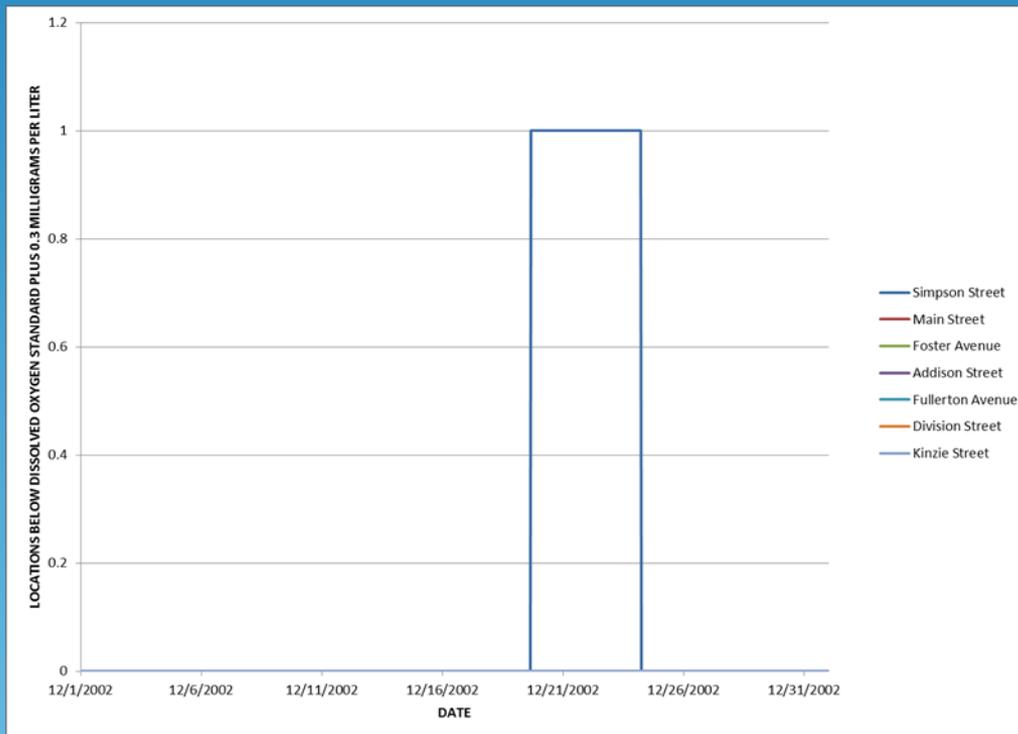
Location	Waterway	Travel Time (hr)
Clark Street	Chicago River main stem	17.0
Wolf Point	South Branch Chicago River	24.9
Jackson Boulevard	South Branch Chicago River	27.0
Loomis Street	South Branch Chicago River	43.2
Cicero Avenue	Chicago Sanitary and Ship Canal	74.5
B & O Railroad	Chicago Sanitary and Ship Canal	94.1
Route 83	Chicago Sanitary and Ship Canal	117.0
Sag Junction	Chicago Sanitary and Ship Canal	118.5
River Mile 11.6	Chicago Sanitary and Ship Canal	120.0
Romeoville Road	Chicago Sanitary and Ship Canal	132.2
Lockport Controlling Works	Chicago Sanitary and Ship Canal	138.7

Travel Times in the CAWS



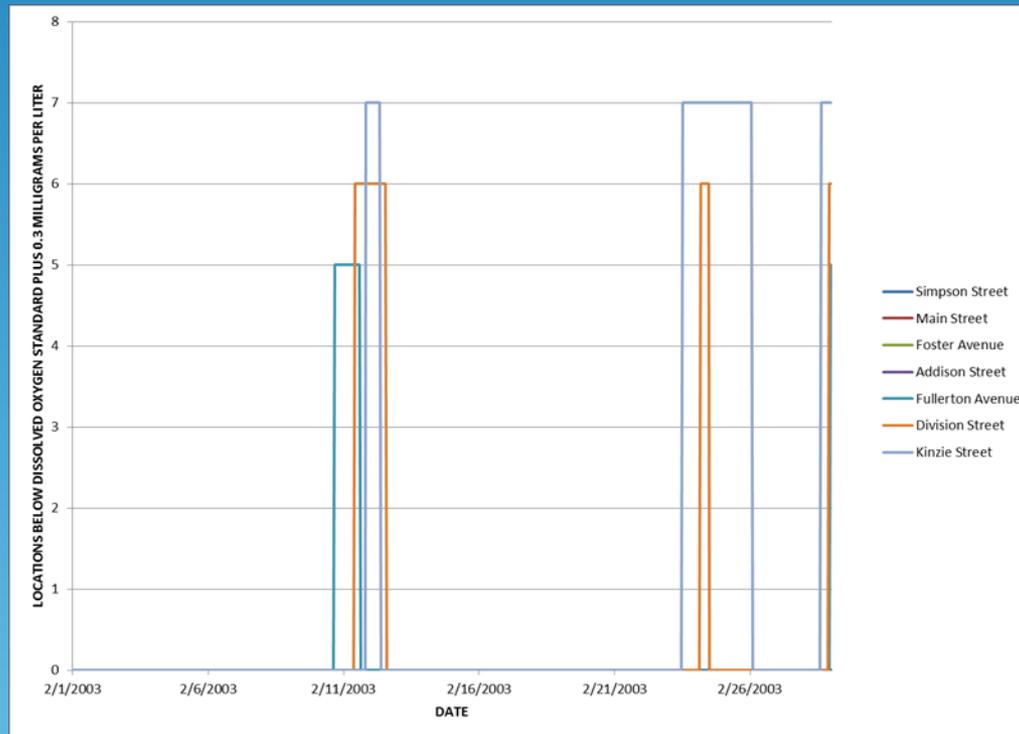
Location	Waterway	Travel Time (hr)
Conrail Railroad	Little Calumet River (north)	24.5
C & W Railroad	Little Calumet River (north)	59.0
Halsted Street	Little Calumet River (north)	94.7
Calumet-Sag Channel junction	Little Calumet River (north)	97.6
Division Street	Calumet-Sag Channel	101.7
Kedzie Street	Calumet-Sag Channel	107.7
Cicero Avenue	Calumet-Sag Channel	116.7
Harlem Avenue	Calumet-Sag Channel	130.1
Southwest Highway	Calumet-Sag Channel	133.8
104 th Street	Calumet-Sag Channel	147.5
Route 83	Calumet-Sag Channel	161.9
Sag Junction	Calumet-Sag Channel	163.5

For the Case of No Discretionary Diversion—Periods not meeting the IEPA Proposed DO Standard



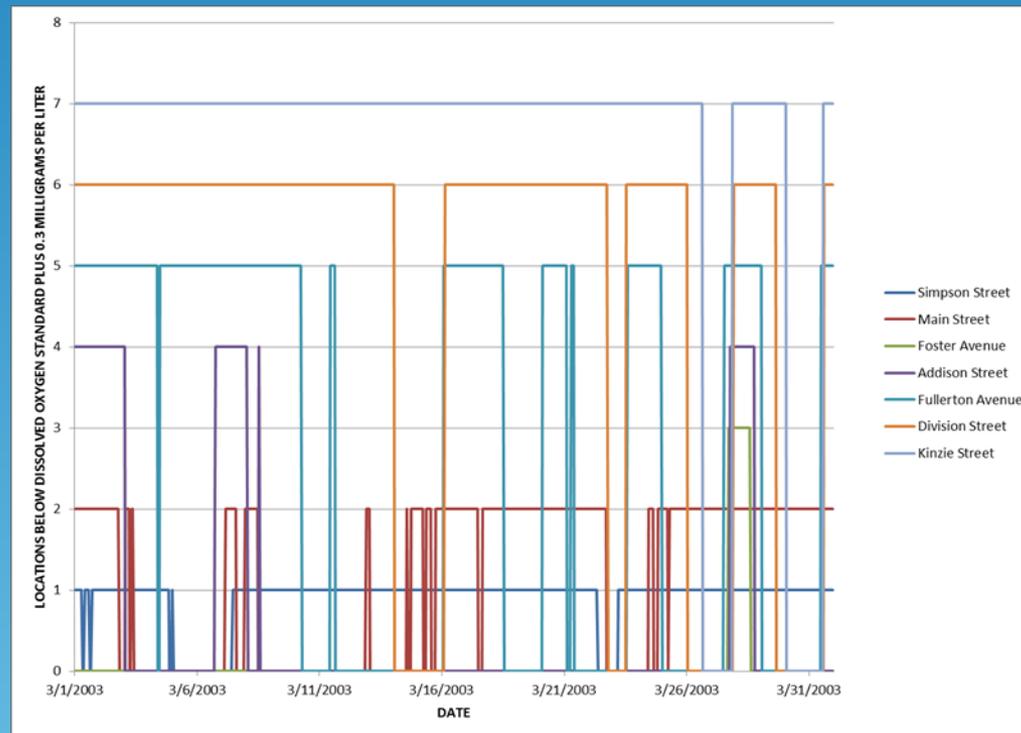
Only Simpson Street experiences noncompliance, solve using Discretionary Diversion “on demand”

For the Case of No Discretionary Diversion—Periods not meeting the IEPA Proposed DO Standard



Solve brief periods of noncompliance at downstream locations through operations of the Devon Avenue and Webster Avenue IASs

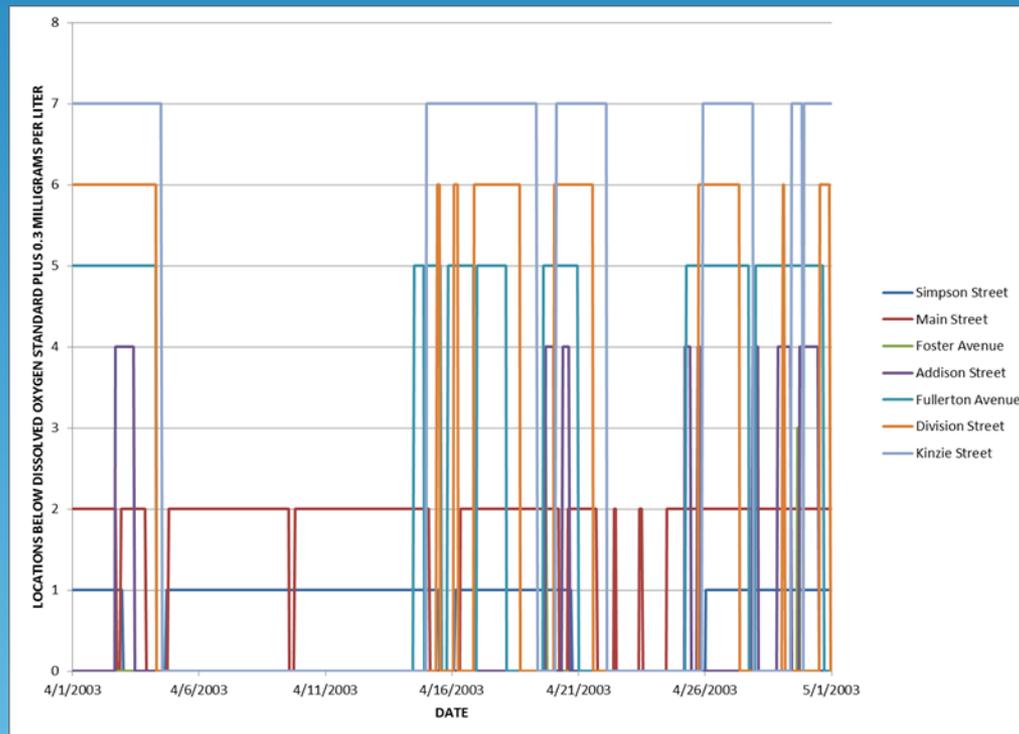
For the Case of No Discretionary Diversion—Periods not meeting the IEPA Proposed DO Standard



Throughout the entire month of March one or more locations on the North Shore Channel or North Branch Chicago River did not meet the DO standards.

Therefore, apply a continuous discretionary diversion throughout the month.

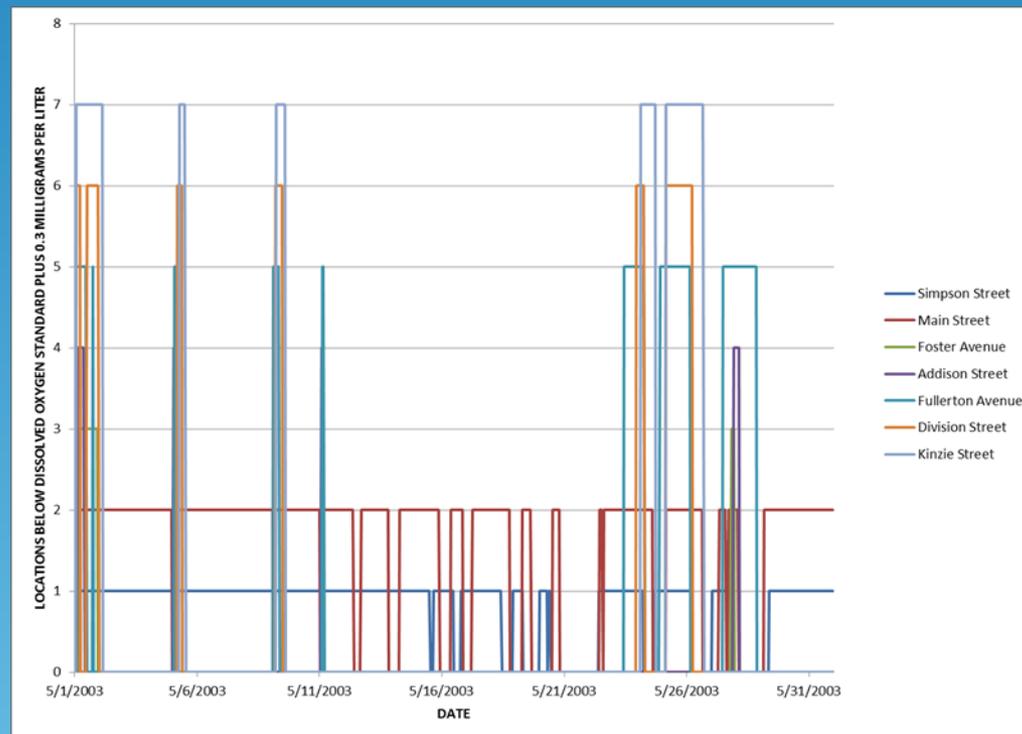
For the Case of No Discretionary Diversion—Periods not meeting the IEPA Proposed DO Standard



Throughout the entire month of April one or more locations on the North Shore Channel or North Branch Chicago River did not meet the DO standards.

Therefore, apply a continuous discretionary diversion throughout the month.

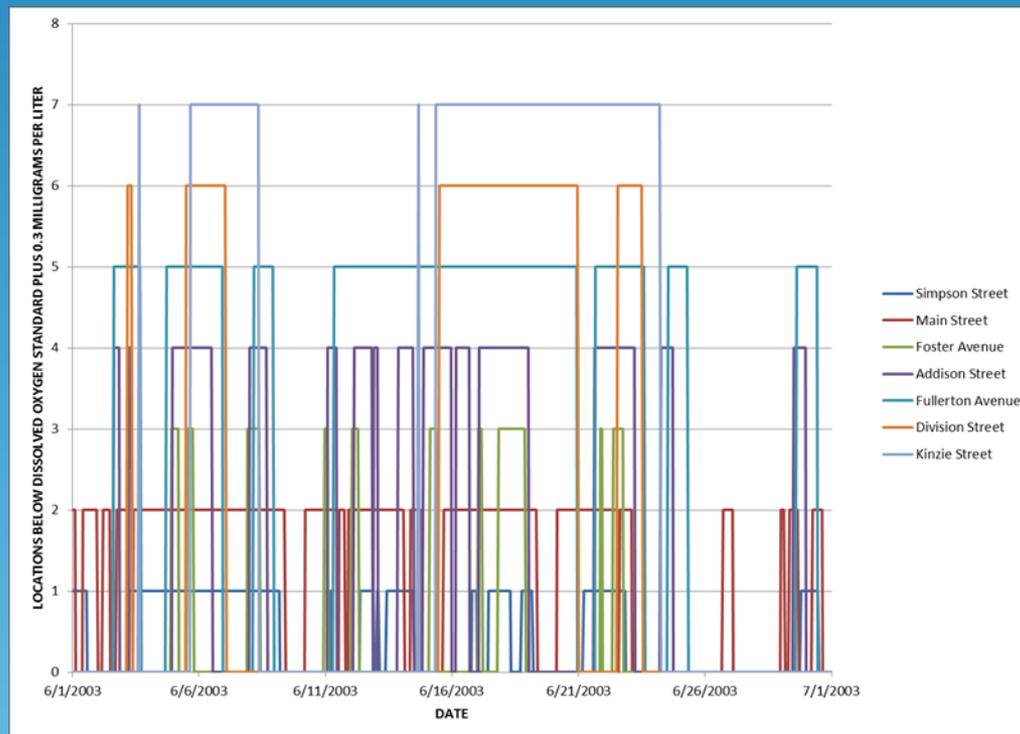
For the Case of No Discretionary Diversion—Periods not meeting the IEPA Proposed DO Standard



Throughout nearly the entire month of May one or more locations on the North Shore Channel or North Branch Chicago River did not meet the DO standards.

Therefore, apply a continuous discretionary diversion throughout the month.

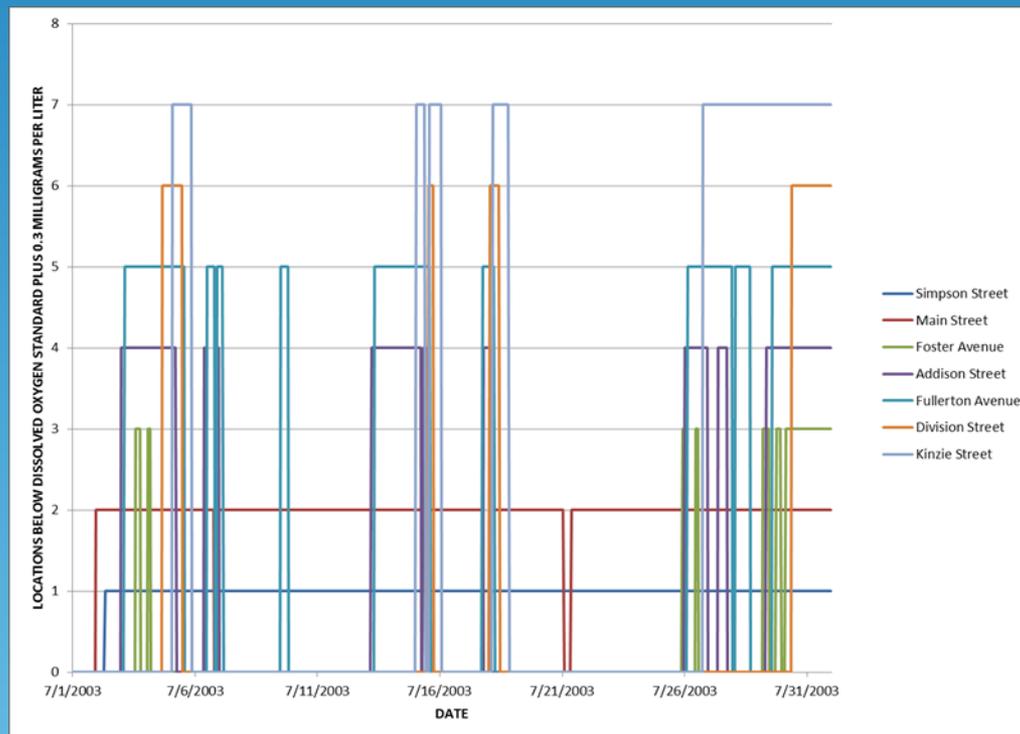
For the Case of No Discretionary Diversion—Periods not meeting the IEPA Proposed DO Standard



Throughout nearly the entire month of June one or more locations on the North Shore Channel or North Branch Chicago River did not meet the DO standards.

Therefore, apply a continuous discretionary diversion throughout the month.

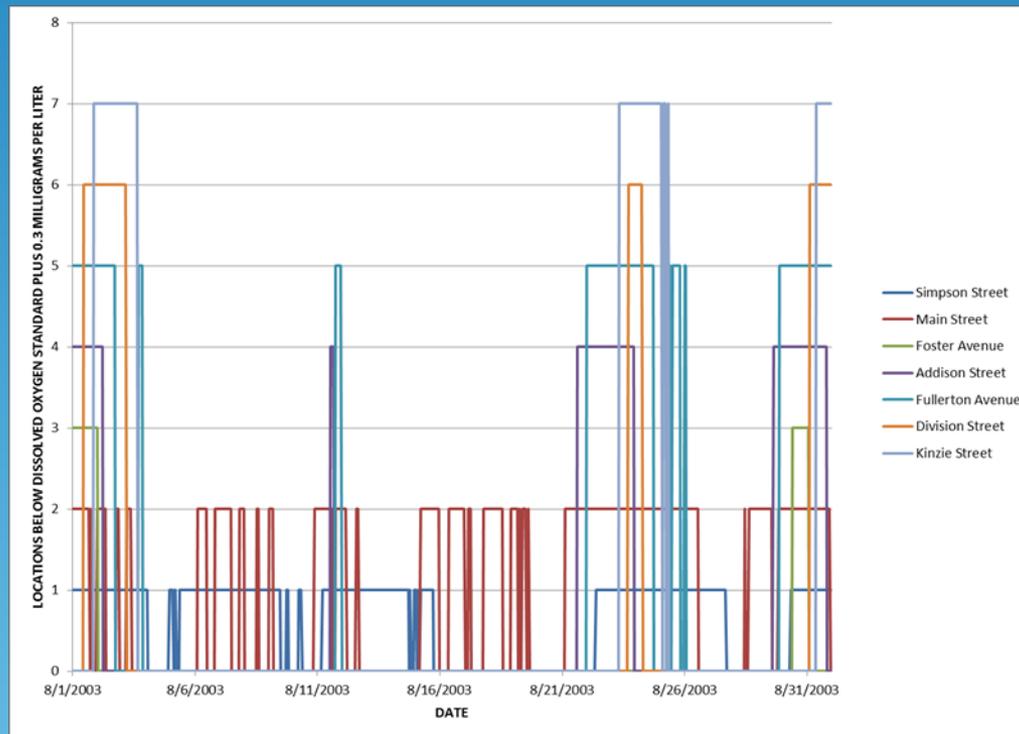
For the Case of No Discretionary Diversion—Periods not meeting the IEPA Proposed DO Standard



Throughout nearly the entire month of July, one or more locations on the North Shore Channel or North Branch Chicago River did not meet the DO standards.

Therefore, apply a continuous discretionary diversion throughout the month.

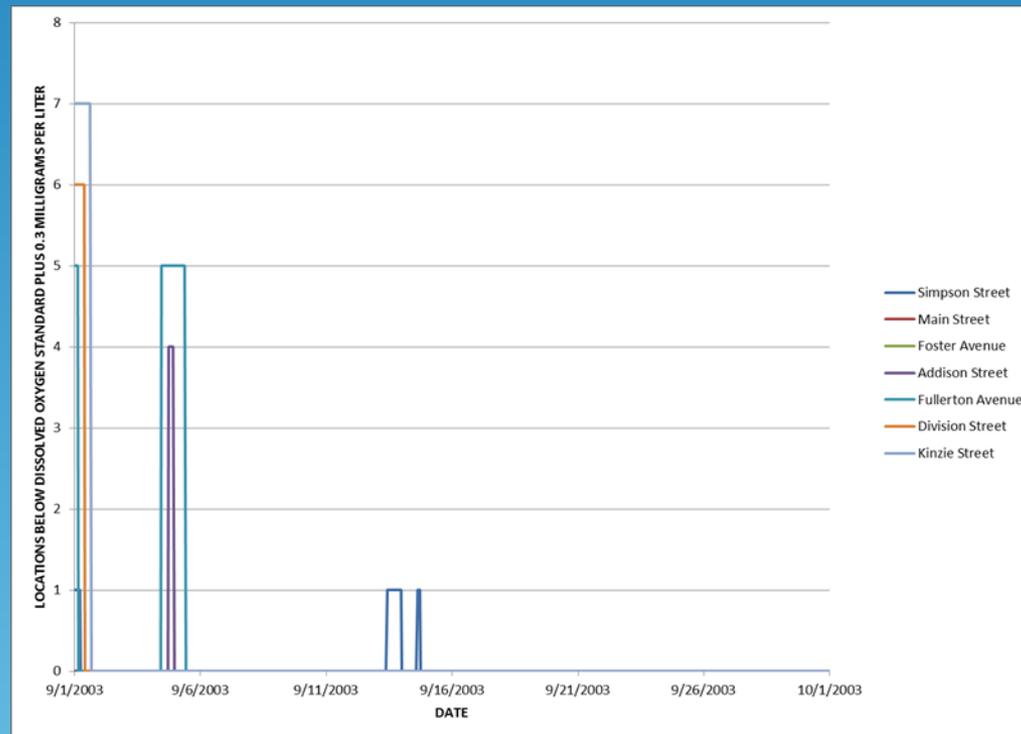
For the Case of No Discretionary Diversion—Periods not meeting the IEPA Proposed DO Standard



Throughout nearly the entire month of August one or more locations on the North Shore Channel or North Branch Chicago River did not meet the DO standards.

Therefore, apply a continuous discretionary diversion throughout the month.

For the Case of No Discretionary Diversion—Periods not meeting the IEPA Proposed DO Standard



- A) For the downstream locations use the IASs to meet the DO standard.
- B) For Simpson Street use discretionary diversion "on demand" to meet the DO standard.

For the Case of No Discretionary Diversion—Periods not meeting the IEPA Proposed DO Standard

Month	Noncompliance Percentage at Loomis Street
March	100.00
April	100.00
May	66.94
June	93.06
July	100.00
August	99.19
September	57.64

Apply a constant discretionary diversion at CRCW for each of these months

Complications for developing a procedure for optimal allocation of discretionary diversion

- The periods during which DO concentrations do not meet the proposed DO standards can be substantially different at Simpson Street and Main Street. Thus, it may be difficult to find a single monitoring point on the UNSC that can adequately identify periods of low DO concentrations at Simpson Street and Main Street so that the discretionary diversion at Wilmette can be triggered to counteract all periods of low DO concentrations throughout the UNSC.

Complications for developing a procedure for optimal allocation of discretionary diversion

- There were 10 periods for which the increase in discretionary diversion needed to start 3-6 hours earlier than the onset of low DO concentrations at the monitoring points.
- In these cases, the travel-time from Wilmette to Simpson Street and/or Main Street required the high DO Lake Michigan water to already be on the way to head off periods of low DO.
- This operation can be done in hind sight for a modeling study, but in practical operations 10-20% of the dry weather events might experience short periods of non-compliance with the DO standards until the high DO Lake Michigan water can spread through the entire UNSC.

Complications for developing a procedure for optimal allocation of discretionary diversion

- Even though the majority of periods could be brought into compliance by initiating the increased discretionary diversion when the DO concentration went below the “threshold” (3.8 mg/L in August-February, and 5.3 mg/L in March-July), the rate at which the discretionary diversion increases still needs some consideration.
- That is, some periods were brought into compliance with an increase of 15 cfs, others required an additional 10 or 15 cfs if DO concentrations continued to drop after the first increase, however, others required another 10 to 100 cfs if DO concentrations continued to drop after the first and second increases.

Components of Optimal Allocation Procedure

- A small discretionary diversion of 15 cfs should be taken even during low DO periods resulting from wet weather in order to shorten the period of non-compliance with the DO standards during wet weather periods.
- If DO concentrations on the UNSC are close to the March DO standard on the last day of February, increased discretionary diversion should start at noon (12:00) on that day to avoid DO standard violations in early March.
- Considering the travel times in the CAWS starting on February 25th may be necessary to ensure compliance at downstream locations.

Phase 3 - Devon In-Stream Aeration Station Operations

- Local DO problems
 - All blowers are off whenever DO concentrations are greater than 5.5 mg/L at the North Branch Pumping Station (NBPS)
 - Start one blower if the DO falls below 5.5 mg/L; leave on until the DO is above 5.5 mg/L, but at least 2 hours
 - Start a second blower if the DO falls below 5 mg/L; leave on until the DO is above 5 mg/L, but at least 2 hours
 - Put on a third blower if the DO at the NBPS falls below 4.5 mg/L; leave on until the DO is above 4.5 mg/L, but at least 2 hours

Phase 3 - Devon In-Stream Aeration Station Operations

- Downstream DO problems
- Any time three blowers are required at Webster, the following modified blower operation at Devon will be implemented

DO at NBPS \leq 7.5 mg/L	1 blower in service
DO at NBPS \leq 6.5 mg/L	2 blowers in service
DO at NBPS \leq 6.0 mg/L	3 blowers in service

Phase 3 - Devon In-Stream Aeration Station Operations - WY 2008

- 1) The operations of the Devon Avenue In-Stream Aeration Station to solve local DO problems is minimal when substantial discretionary diversion is taken at Wilmette
- 2) The Devon Avenue In-Stream Aeration Station is operated more frequently to raise DO concentrations downstream from Webster Avenue than it is to mitigate DO problems at the NBPS (2675.5 hr vs. 1080 hr)



Comments
Questions & Answers

