Protecting Our Water Environment

Metropolitan Water Reclamation District of Greater Chicago

MONITORING AND RESEARCH DEPARTMENT

REPORT NO. 18-1

GUIDELINES FOR "OPTIMAL" WITHDRAWAL OF DISCRETIONARY DIVERSION TO AND OPERATION OF THE AERATION STATIONS ON THE CHICAGO AREA WATERWAY SYSTEM

January 2018

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

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By

Charles S. Melching, Ph.D., P.E.

Monitoring and Research Department
Edward W. Podczerwinski

January 2018

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100 EAST ERIE STREET CHICAGO, ILLINOIS 60611-3154 312.751.5190 f: 312.751.5194

Edward W. Podczerwinski, P.E.
Director of Monitoring and Research
podczerwinskie@mwrd.org

January 11, 2018

Mr. Jim Casey
Chief, Lake Michigan Management Section
Illinois Department of Natural Resources
One Natural Resources Way
Springfield, IL 62702-1271

Dear Mr. Casey:

Subject: Transmittal of Report "Guidelines for 'Optimal' Withdrawal of Discretionary Diversion to and Operation of the Aeration Stations on the Chicago Area Waterway System"

The Illinois Department of Natural Resources' Final Administrative Decision regarding the Metropolitan Water Reclamation District of Greater Chicago's (District's) Petition for Modification of Lake Michigan Water Allocation Permit (Number LMO-14-5) required that the District report on its optimization modeling and plan referenced in the record of this proceeding. Melching Water Solutions (MWS) has completed the modeling study of the report entitled "Guidelines for 'Optimal' Withdrawal of Discretionary Diversion to and Operation of the Aeration Stations on the Chicago Area Waterway System" for the District with recommendations to optimize discretionary diversion and existing aeration station operations to achieve maximum attainment of the dissolved oxygen water quality standards in the Chicago Area Waterway System (CAWS). The MWS report is enclosed and will be uploaded to the District's website on the "Water Quality Monitoring" webpage.

The optimization modeling study assumed an annual discretionary diversion allocation of 220 cubic feet per second, as set forth on Page 79 of the Final Administrative Decision for Water Years 2018–2030. Using MWS' recommendations for optimizing discretionary diversion and aeration stations, the simulated dissolved oxygen concentrations met water quality standards 95 percent of the time or more in the CAWS for modeled water years.

The District has begun to implement the recommendations described in the attached report through automated operational controls. We look forward to monitoring the benefits of this optimization plan in the CAWS and practicing adaptive management of our operations to work towards actual waterway conditions that reflect the improvements suggested by the modeled scenarios.

Subject: Transmittal of Report "Guidelines for 'Optimal' Withdrawal of Discretionary Diversion to and Operation of the Aeration Stations on the Chicago Area Waterway System"

If you have any questions, please feel free to call Jennifer Wasik, Principal Environmental Scientist, at 708-588-4063.

Very truly yours,

Edward W. Podczerwinski, P.E.
Director
Monitoring and Research

EWP:HZ:JW:lf/cm
Enclosure
cc: S. Morakalis
J. Murray
H. Zhang
A. Cox
J. Wasik

Guidelines for "Optimal" Withdrawal of Discretionary Diversion to and Operation of the Aeration Stations on the Chicago Area Waterway System

Report Prepared for the Metropolitan Water Reclamation District of Greater Chicago

Charles S. Melching, Ph.D., P.E.

12/28/2017

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Chapter 1 – INTRODUCTION

1.1 Background

The City of Chicago, Illinois, is located at the southern end of Lake Michigan, the fifth largest freshwater lake in the world (by surface area) that serves as the water supply for Chicago and surrounding communities. In the 1800s, Chicago built a network of combined sewers to drain stormwater and wastewater from the city to the Chicago River and then to Lake Michigan. During large storms the polluted combined sewer flows would extend far enough into Lake Michigan that they would enter the water supply intakes for Chicago. This contributed to very high levels of death by typhoid fever in Chicago, peaking at more than 170 per 100,000 residents in 1891 (Hill, 2000).

In 1889, the Sanitary District of Chicago (later known as the Metropolitan Sanitary District of Greater Chicago [MSD] and now known as the Metropolitan Water Reclamation District of Greater Chicago [MWRDGC]) was formed by the State of Illinois, and charged with building a canal that would carry flow from the polluted Chicago River away from Lake Michigan through the low continental divide west of Chicago to the Des Plaines River, Illinois River, and ultimately the Mississippi River (Lanyon, 2012). In 1892 construction began and in 1900 the Chicago Sanitary and Ship Canal (CSSC) was opened to reverse the flow of the Chicago River, thus, diverting the wastewater and combined sewer overflows from Chicago away from Lake Michigan and toward the Mississippi River. Two additional channels were later opened to improve water quality in the Chicago area: (1) the North Shore Channel (NSC, completed 1910) to flush water of poor quality from the North Branch Chicago River (NBCR) and (2) the Calumet-Sag Channel (completed 1922) to divert the Calumet River away from Lake Michigan. The lower portion of the NBCR, South Branch Chicago River (SBCR), Chicago River main stem, Calumet River, and Little Calumet River (north) also have been widened, deepened, and straightened to efficiently carry treated wastewater away from Lake Michigan.

The system of constructed and altered waterways described previously is known as the Chicago Area Waterway System (CAWS). In total, the CAWS is a 76.3 mi branching network of navigable waterways controlled by hydraulic structures in which the majority of flow is treated sewage effluent and there are periods of combined sewer overflows (CSOs). The dominant uses of the CAWS are conveyance of treated municipal wastewater, commercial navigation, and flood control. The CAWS receives pollutant loads from 3 of the largest wastewater treatment plants in the world, nearly 240 gravity CSOs, 3 CSO pumping stations, eleven tributary streams or drainage areas, and direct diversions from Lake Michigan. The water quality in the CAWS also is affected by the operation of five Sidestream Elevated Pool Aeration (SEPA) stations and two in-stream aeration stations (IASs). The Calumet River and Chicago River systems are shown in Figure 1.1.

1.2 Dissolved Oxygen Standards

In 2007, the Illinois Pollution Control Board (IPCB) began considering Rule R08-9 proposed by the Illinois Environmental Protection Agency (IEPA, 2007) for an upgrading of the water quality standards for the CAWS. On March 18, 2010, the IPCB divided Rule R08-9 into 4 subdockets:

1) Subdocket A dealt with the issues related to recreational use designations, 2) Subdocket B addressed issues relating to disinfection and whether or not disinfection may or may not be necessary to meet those use designations, 3) Subdocket C addresses the issues related to aquatic life use designations, and 4) Subdocket D addresses the issues dealing with water quality standards and criteria that are necessary to meet the aquatic life use designations (IPCB, 2014). On February 21, 2013, the IPCB added Subdocket E to Rule R08-9 to examine issues surrounding the South Fork of the South Branch of the Chicago River (known as Bubbly Creek). Subdockets C and D were published by the IPCB (2014, 2015) on February 6, 2014 and June 18, 2015, respectively, and Subdocket E was ordered closed by the IPCB on May 21, 2015. The use of the existing aeration stations and the withdrawal of discretionary diversion cannot directly affect DO conditions in Bubbly Creek. Thus, high attainment of the DO standards published in Subdockets C and D is the goal of this optimization study.

In Subdocket C the IPCB (2014) designated the NSC, NBCR, SBCR, Little Calumet River (north), Calumet-Sag Channel, Grand Calumet River, and Calumet River from Lake Michigan to its confluence with the Grand Calumet River as CAWS Aquatic Life Use (ALU) A waters: the CSSC as a CAWS and Brandon Pool ALU B water, and the Chicago River main stem as a General Use water. While Subdocket E remains under review Bubbly Creek has the designation of an Indigenous Aquatic Life Use water (IPCB, 2015). For these different aquatic life uses the following DO standards must be met. For General Use waters:

1) during the period of March through July:

    A. 6.0 mg/L as a daily mean averaged over 7 days; and

    B. 5.0 mg/L at any time; and

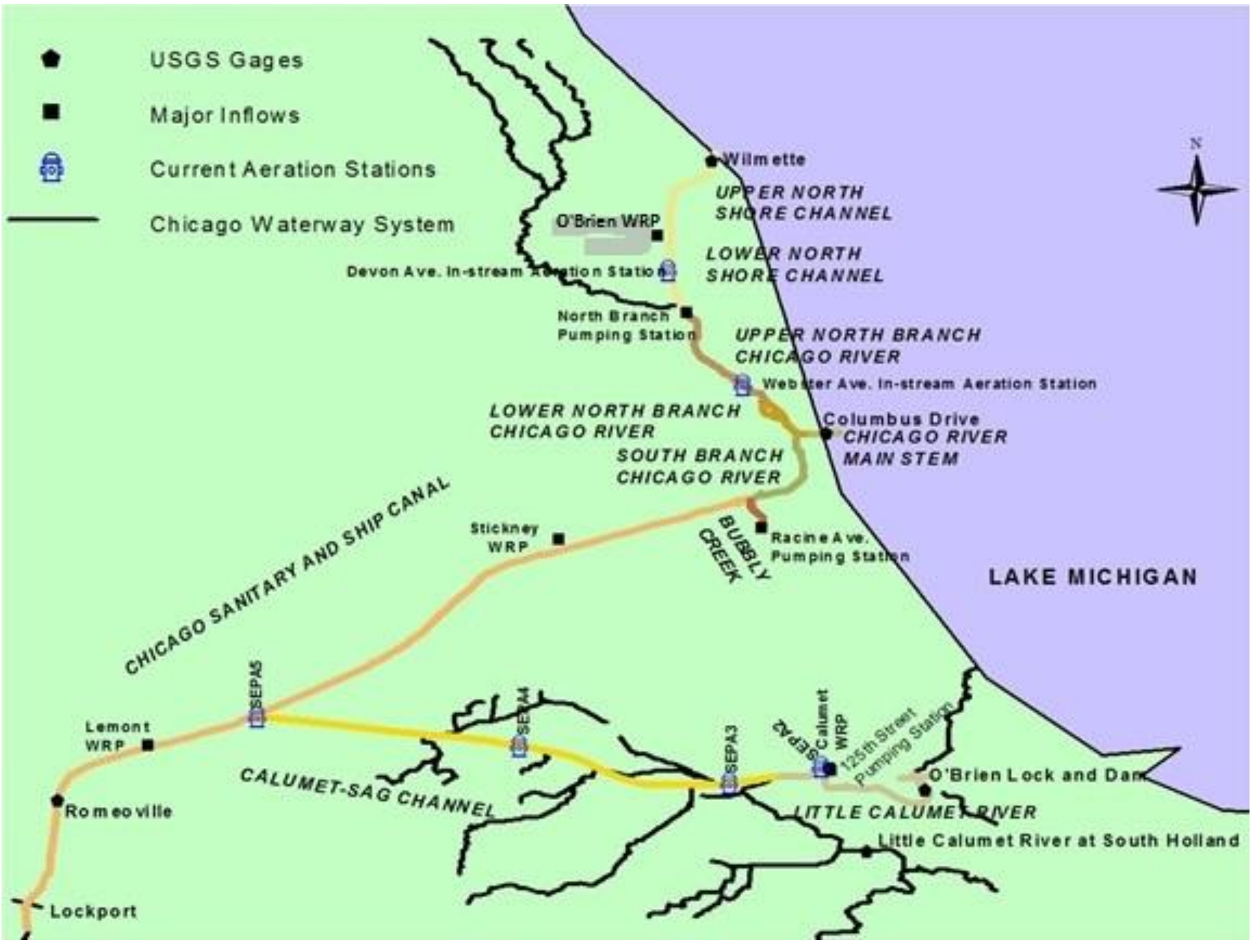

Figure 1.1. Schematic diagram of the Calumet and the Chicago River systems (note: the upstream U.S. Geological Survey gages compose the upstream boundaries of the simulation model)

2) during the period of August through February:

    A. 5.5 mg/L as a daily mean averaged over 30 days;

    B. 4.0 mg/L as a daily minimum averaged over 7 days; and

    C. 3.5 mg/L at any time.

For CAWS ALU A waters:

1) during the period of March through July:

    A. 5.0 mg/L at any time; and

2) during the period of August through February:

A. 4.0 mg/L as a daily minimum averaged over 7 days; and

B. 3.5 mg/L at any time.

For CAWS and Brandon Pool ALU B waters:

1) 4.0 mg/L as a daily minimum averaged over 7 days; and

2) 3.5 mg/L at any time.

Finally, for Indigenous Aquatic Life waters the DO concentration shall not be less than 4.0 mg/L at any time.

1.3 Project Objective and Scope

The MWRDGC operates the O'Brien, Calumet, Stickney, and Lemont Water Reclamation Plants (WRPs) in accordance with their National Pollutant Discharge Elimination System (NPDES) permits, and the NPDES limits are rather stringent compared to typical WRPs throughout the U.S. Over the last ten years (2007-2016), for each year the Calumet, O'Brien, and Lemont WRPs received the National Association of Clean Water Agencies (NACWA) Platinum Award for 100% compliance with the NPDES effluent standards. The Stickney WRP achieved this standard for 2007-2012 and achieved the NACWA Gold Award in 2014 and 2015 and the NACWA Silver Award in 2013 and 2014 (with the lowest compliance being 99.7% in 2013). Despite this outstanding performance the CAWS is still prone to low DO concentrations because of its low slope and high depth that limits natural reaeration of the water.

The MWRDGC voluntarily manages the State of Illinois' allocation of discretionary diversion from Lake Michigan to maintain the CAWS in a "reasonably satisfactory sanitary condition" as per U.S. Supreme Court Decree (Wisconsin v. Illinois, 388 U.S. 426 (1967)). The MWRDGC also operates the SEPA and IAS stations to assist the State in attaining the relevant DO standards for the CAWS. The discretionary diversion flows are withdrawn from Lake Michigan at the Wilmette Pumping Station (WPS), Chicago River Controlling Works (CRCW), and O'Brien Lock and Dam (O'Brien L&D). In order to determine operational procedures for the aeration stations and withdrawal of discretionary diversion to maximize the attainment of the DO standards a two-part water-quality modeling study of the CAWS was initiated between the MWRDGC and Melching Water Solutions in 2012. The modeling was done using the DUFLOW model applied to the CAWS, which is described in Section 1.4.

Part 1 of the project was titled: "Agreement to Evaluate the Allocation of Discretionary Diversion from Lake Michigan" (PO# 3084849). The Tasks of Part 1 included using the DUFLOW water-quality model of the CAWS to:

1. Evaluate the allocation of discretionary diversion from Lake Michigan spatially and temporally to yield DO concentrations that maximize the attainment of the DO standards for the CAWS, particularly in the North Shore Channel and the Little Calumet River;
2. Examine the proper DO monitoring locations in the system for monitoring the effectiveness of allocating lake discretionary diversion water to improve water quality in various segments of the CAWS;
3. Evaluate the changes in operations of the SEPA stations necessary to supplement or counteract the effects of the changes in discretionary diversion on the Calumet-Sag Channel;

4. Evaluate the effectiveness of the Devon Avenue IAS and determine if there is an alternative location where this station would be more effective.

It should be noted that Task 4 found that the Devon Avenue IAS was effective and should be refurbished and its operations should be revised, as was detailed in a report (Melching, 2014) that was provided to the IEPA on June 8, 2016. Task 4 also evaluated improved operational procedures for the Webster Avenue IAS. Thus, Task 4 determined improved operational guidance for both IASs.

Tasks 1-4 were evaluated considering the three representative Water Years (WYs) considered in the Great Lakes and Mississippi River Interbasin Study (GLMRIS) (Melching and Liang, 2013; Melching et al., 2015)—namely WY 2001 (normal year), WY 2003 (dry year), and WY 2008 (wet year). Melching and Liang (2013) provide a detailed discussion of the selection of these representative years.

Part 2 of the project is titled: "DUFLOW Chicago Area Waterway System (CAWS) Water Quality Model for Optimization Discretionary Diversion" (PO# 3093033). The objective of Part 2 was to build overall operational guidance for the aeration stations and the withdrawal of discretionary diversion. Part 1 of the project determined optimal guidance for each of the representative years individually, and Part 2 of the project sought to determine a balanced set of guidelines that would achieve high attainment of the DO standards for the CAWS at all locations and for all three representative years.

Part 1 of the project started in 2012, and, thus, the operational guidelines developed in Part 1 focused on conditions corresponding to the estimated actual inflows to the CAWS for the representative years. In 2015 the Thornton Reservoir, which collects CSOs from the Calumet River system, became operational. At the end of 2017 the first stage of the McCook Reservoir, which collects CSOs from the Chicago River system, became operational. Part 2 of the project started in 2017, thus, it was decided that the operational guidance should be developed and tested for inflow conditions representative of CSOs with the Thornton Reservoir and Stage 1 of the McCook Reservoir operational. As part of the GLMRIS study, the CSO flows, WRP flows, and downstream boundary conditions were modified based on CSO simulations from U.S. Army Corps of Engineers (USACE) models (described in detail in Espey et al. (2004)) of the watershed, major interceptor combined sewers, and the Tunnel and Reservoir Plan (TARP) components for the case of Thornton Reservoir and Stage 1 of the McCook Reservoir operational. These modified flows and boundary conditions are known as the Baseline Conditions in the GLMRIS study (Melching and Liang, 2013).

The operational guidelines developed in Part 1 of the project also considered an allowable total discretionary diversion of 270 cfs on average over the WY. On September 22, 2016, the Illinois Department of Natural Resources (IDNR) issued its Final Administrative Decision on a Petition for Modification of Allocation Permit by Metropolitan Water Reclamation District of Greater Chicago (LMO-14-5). In this decision the allowable discretionary diversion was reduced from 270 cfs to 220 cfs beginning in WY 2018.

Thus, Part 2 of the project required not just balancing operational guidelines for the three representative years but also adjusting the year by year guidelines to reflect the changed inflows relative to Part 1 of the project, i.e. the GLMRIS Baseline Conditions were utilized and the annual discretionary diversion was limited to 220 cfs.

1.4 Development and Application of the DUFLOW Water-Quality Model to the CAWS

By 1998 the MWRDGC knew they would soon be faced with a number of difficult management issues including the impact of reduced discretionary diversions from Lake Michigan for water-quality improvement in the summer (partly the objective of this study), the outcome of a use attainability analysis for the CAWS, among other issues (Lanyon and Melching, 2001). Thus, in August 1998 they installed a network of 20 continuous DO and temperature measurement sondes throughout the CAWS (mainly on the Chicago River system). In July 2001 an additional 12 measurement sondes were added to the Calumet River system. From 1998 to the present the number of sondes in the network has increased and decreased such that 15 are still active on the CAWS, and 32 were active for all or part of WY 2003. These sondes provide hourly temperature and DO data that could be used to calibrate and verify a water-quality model for the CAWS. Because of the dynamic nature of the CAWS a model capable of simulating hydraulics and water-quality processes under unsteady-flow conditions was needed to assist the MWRDGC in water-quality management and planning decision making processes.

In 2000, a number of models were available for simulation of water quality under unsteady-flow conditions. Some models had been developed by U.S. government agencies, for example, the

Water-Quality Analysis and Simulation Program Version 5 (WASP5, Ambrose et al., 1993), developed by the U.S. Environmental Protection Agency (USEPA) and the Branched Lagrangian Transport Model (BLTM, Jobson and Schoellhamer, 1987; Jobson, 1997), developed by the U.S. Geological Survey (USGS). The water-quality capabilities of these models are quite robust. However, the hydrodynamic portions of these models were less efficient in 2000. The hydrodynamic model suggested for coupling with WASP5 had a history of not performing well for one-dimensional unsteady flows in river systems. BLTM requires the development of a separate hydrodynamic model for the river system, and the computed stages and velocities must be transformed from the hydrodynamic-model output to the water-quality model input.

The DUFLOW Model (DUFLOW, 2000) was jointly developed in The Netherlands by the Rijkswaterstaat, International Institute for Hydraulic and Environmental Engineering of the Delft University of Technology, STOWA (Dutch acronym for the Foundation for Applied Water Management Research), and the Agricultural University of Wageningen. DUFLOW was considered a reasonable alternative to WASP (in fact, it included an option to use the WASP4 (Ambrose et al., 1988) routines to compute water-quality in the water column) and BLTM. DUFLOW has been applied with great success to several European river systems (e.g., Manache and Melching, 2004). In the study of Manache and Melching (2004), DUFLOW was found to be computationally robust with few computational failures encountered over thousands of runs. It allows several options for the simulation of water quality in stream systems, including allowing the user to add relations for the simulation of additional water-quality properties or constituents not originally included in the preprogrammed DUFLOW options. Finally, DUFLOW's compatibility with Geographical Information Systems (GIS) facilitated representation and display of the river system, its compatibility with Microsoft Windows facilitated ease of use and the import and export of input and results to and from Microsoft Excel, and its relatively low license cost made it affordable for many applications. Given these capabilities and advantages, DUFLOW was selected for modeling of the CAWS, and the MWRDGC entered into an agreement with Marquette University in 2000 to adapt the DUFLOW model for simulation of the hydraulics and water-quality processes of the CAWS. In the first several years of the adaptation of the DUFLOW model for the CAWS the MWRDGC convened an ad-hoc committee of representatives from government agencies in Illinois—USEPA, Region 5; USACE, Chicago District; USGS, Illinois District; IDNR-Office of Water Resources (IDNR-OWR); and IEPA—to keep these agencies informed of and to get their input on the development of the model.

To simulate water quality in the CAWS the DUFLOW water-quality simulation option that adds the DiToro and Fitzpatrick (1993) sediment flux model to the WASP4 (Ambrose et al., 1988) model of constituent interactions in the water column is applied. DUFLOW distinguishes among transported material that flows with water, bottom materials that are not transported with the water flow, and pore water in bottom materials that are not transported but that can be subject to similar water-quality interactions to those for the water column. Flow movement and constituent transport and transformation are simulated within DUFLOW and constituent transport is defined by advection and dispersion. The flow simulation in DUFLOW is based on the one-dimensional (1-D) partial differential equations that describe unsteady flow in open channels (de Saint-Venant equations). These equations are the mathematical translation of the laws of conservation of mass and momentum.

Marquette University successfully applied the DUFLOW water-quality model to the CAWS for several purposes: i) Alp and Melching (2004) used the DUFLOW model to investigate the possible effects of a change in navigational water level requirements and the navigation make-up diversion of water from Lake Michigan during storm events on water-quality in the CAWS, ii) Neugebauer and Melching (2005) developed a method to verify the calibrated DUFLOW model under uncertain storm loads, iii) Manache and Melching (2005) applied the DUFLOW model to simulate fecal coliform concentrations in the CAWS under unsteady flow conditions; iv) Alp and Melching (2006) evaluated the effectiveness of flow augmentation, supplemental aeration, and CSO treatment acting individually to improve DO conditions in the CAWS; v) Melching et al. (2010, 2013) developed integrated strategies that combined flow augmentation and supplemental aeration in the CAWS so that the simulated DO concentrations equaled or exceeded various proposed DO standards for the CAWS; and vi) Melching and Liang (2013) and Melching et al. (2015) applied the DUFLOW model to simulate the effects of ecological/hydrological separation of the Great Lakes and Mississippi River watersheds in the CAWS on water quality in the CAWS and loads to Lake Michigan as part of the USACE GLMRIS evaluations.

The hydraulic component of the DUFLOW (2000) unsteady-flow model for the CAWS was calibrated and verified by Marquette University in 2003. The ability of the model to simulate unsteady flow conditions was demonstrated by comparing the simulation results to measured data for eight different periods between August 1, 1998 and July 31, 1999 (Shrestha and Melching, 2003). A summary of the verification of the DUFLOW hydraulic model is given in Table 1.1 where the correlation coefficient and percentage of errors relative to the flow depth less than or equal to 5% for the simulated and measured hourly water levels are listed. As shown in Table 1.1 the vast majority of the comparisons show high correlation between measured and simulated water levels and very high frequency of errors less than 5% relative to the flow depth indicating an excellent hydraulic model.

Table 1.1. Correlation coefficient and percentage of the hourly water-surface elevations for which the error in simulated versus measured water-surface elevations relative to the depth of flow (measured from the thalweg of the channel) is less than 5% for Water Years 2001, 2003, and 2008. (NA means "not available")

Location	Correlation Coefficient			Percentage ≤ 5% of depth		
	2001	2003	2008	2001	2003	2008
Wilmette Pumping Station	0.94	0.82	NA	96	78	NA
Chicago River Controlling Works	0.87	0.77	NA	100	100	NA
O'Brien Lock and Dam	0.75	0.64	NA	100	100	NA
Lawrence Avenue	0.74	0.42	0.78	86	65	50
Grand Avenue	NA	NA	0.86	NA	NA	99
Western Avenue	0.88	0.77	0.79	100	100	99
Willow Springs Road	0.84	0.81	0.91	100	100	99
Southwest Highway	0.67	0.47	0.74	97	93	83
Calumet-Sag Junction	0.82	0.84	0.79	100	100	99
Lemont	NA	NA	0.85	NA	NA	100
Romeoville	0.92	0.91	NA	100	100	NA

The DUFLOW water-quality model was calibrated and verified (Alp and Melching, 2006; Neugebauer and Melching, 2005) for the periods of July 12 to November 9, 2001 and May 1 to September 23, 2002, respectively. After these initial calibrations and verifications, the DUFLOW hydraulic and water-quality models were calibrated and verified in more detail for the full 2001 and 2003 WYs by Melching et al. (2010) and for the full 2008 WY by Melching and Liang (2013). The relative Root Mean Square Error (i.e. Root Mean Square Error divided by the range of the data) is a commonly used measure of the accuracy of water quality models. For example, in the Quality Assurance Project Plan for the Illinois River (in Arkansas and Oklahoma) Watershed Nutrient Modeling Development (Baker, 2013) for the calibration and validation of the Environmental Fluid Dynamics Code applied to Lake Tenkiller (OK) the targets for acceptable calibration and validation were average relative Root-Mean-Square Errors of ±20% for DO. Table 1.2 lists the relative RMSE of the DUFLOW model of the CAWS. Nearly all (55 of 64, 85.9%) of the relative Root Mean Square Errors in Table 1.2 are below the simulation quality target of 20%. Only in the boundary regions (i.e. NSC upstream of the O'Brien WRP, Little Calument River (north) upstream of the Calumet WRP, and the Chicago River main stem), where the hydraulics are difficult to simulate, are prone to relative RMSE greater than 20%. Therefore, the DUFLOW model of the CAWS is well suited for the study detailed here.

1.5 Report Organization

Chapter 2 describes the development of the guidelines for withdrawal of discretionary diversion at the WPS and the operation of the Devon Avenue and Webster Avenue IASs in Part 1 of this project. Chapter 3 describes the development of the guidelines for withdrawal of discretionary diversion at the O'Brien Lock and Dam and the operation of SEPA stations 2-4 in Part 1 of this project. Chapter 4 describes the "year specific" optimal guidelines for withdrawal of discretionary diversion and operation of all aeration stations developed for WYs 2001, 2003, and 2008 in Part 2 of this project. Chapter 5 details the development of guidelines for withdrawal of discretionary diversion that balances the "optimal" allocation for each individual WY into an overall system that yields good results for all three years. Chapter 6 summarizes the "optimal" guidelines for the withdrawal of discretionary diversion and the operation of the aeration stations in the CAWS.

Table 1.2. Average Relative Root Mean Square Error of simulated dissolved oxygen concentrations for the CAWS. (note: NA means "not available" and represents the case that no measured data were available at this location for that Water Year)

Location	2001	2003	2008
Simpson Street	20.09	25.11	NA
Main Street	20.31	18.31	14.31
Foster Avenue	NA	NA	7.77
Addison Street	7.43	10.06	7.12
Fullerton Avenue	10.20	14.18	8.94
Division Street (NBCR)	12.46	12.68	NA
Kinzie Street	10.27	13.71	14.10
Clark Street	17.52	29.13	13.23
Jackson Boulevard	12.80	19.94	NA
Loomis Street	NA	NA	20.53
Cicero Avenue (CSSC)	15.22	14.29	14.86
Baltimore & Ohio Railroad	11.49	15.12	14.28
Route 83 (CSSC)	14.35	16.44	12.56
River Mile 302.6	13.07	12.88	NA
Romeoville Road	13.07	14.22	NA
Lockport Controlling Works	13.08	12.88	15.49
Conrail Railroad	22.94	22.29	NA
Central & Wisconsin Railroad	24.74	21.74	21.90
Halsted Street	14.14	11.69	7.04
Division Street (Calumet-Sag Channel)	11.51	9.93	NA
Kedzie Street	8.94	10.01	NA
Cicero Avenue (Calumet-Sag Channel)	13.65	11.47	9.74
Harlem Avenue	14.93	12.79	NA
Southwest Highway	15.34	10.75	NA
104th Avenue	14.40	17.49	15.99
Route 83 (Calumet-Sag Channel)	14.78	13.59	12.28

Chapter 2 – Operational Guidance for the North Shore Channel and North Branch Chicago River

2.1 Introduction

There are two means to improve DO concentrations on the NSC and lower NBCR—namely, withdrawal of discretionary diversion at the WPS and operation of the Devon Avenue and Webster Avenue IASs. In this Chapter, the determination of DO monitoring locations where detection of low DO concentrations would trigger the withdrawal of discretionary diversion at the WPS and the amount of these diversions are discussed on the basis of Part 1 of this project. Also, in this Chapter, the DO monitoring locations and the operational guidance for the Devon Avenue and Webster Avenue IASs are discussed on the basis of Part 1 of this project. The operational guidance derived for the NSC and lower NBCR on the basis of Part 1 of this project essentially compose the final operational guidance for these waterways, except for some small changes in the amount and timing of discretionary diversion at the WPS detailed in Chapters 4 and 6.

2.2 Operational Guidance for the Withdrawal of Discretionary Diversion at the Wilmette Pumping Station

In the development of the operational guidance for the withdrawal of discretionary diversion at the WPS a continuous DO monitor was needed on the NSC upstream of the O'Brien WRP. Ideally this monitoring location should be prone to high non-attainment of the DO standards and should be close enough to the WPS so that discretionary diversion taken "on demand" can remedy the conditions resulting in low DO concentrations at this location. The operational "triggers" for taking discretionary diversion based on DO concentrations observed at the DO monitoring location will be adjusted to ensure high attainment of the DO standards throughout the NSC upstream of the O'Brien WRP.

Figure 2.1 shows the number of hours at various locations on the NSC upstream of the O'Brien WRP not attaining the at any time DO standard for the case of no discretionary diversion at the WPS and actual CSO inflows to the CAWS for each of the representative WYs—2001, 2003, and 2008. Especially considering WYs 2001 and 2003, it is clear that the reach between Simpson Street (River Mile (RM) 339.5) and Dempster Street (RM 338.0) is prone to high non-attainment of the at any time DO standard. Once Main Street (RM 337.5) is reached, the non-attainment of the at any time DO standard generally is much lower (i.e. the frequency of periods exceeding the at any time DO standard generally is much higher). Thus, a DO monitoring point between Simpson Street and Dempster Street, for which rules for discretionary diversion could be derived, would probably yield high attainment of the DO standards along the NSC upstream of the O'Brien WRP using a minimal amount of discretionary diversion at the WPS.

The MWRDGC determined that Emerson Street (RM 338.8) and Church Street (RM 338.5) are potential locations for DO monitors between Simpson Street and Dempster Street. The MWRDGC also wanted to check the performance of using DO monitors at Church Street and Emerson Street against that of using the existing DO monitor at Main Street. Thus, the use of DO monitors at Emerson Street, Church Street, and Main Street to trigger the withdrawal of discretionary diversion from the WPS was evaluated for the three representative WYs of 2001, 2003, and 2008.

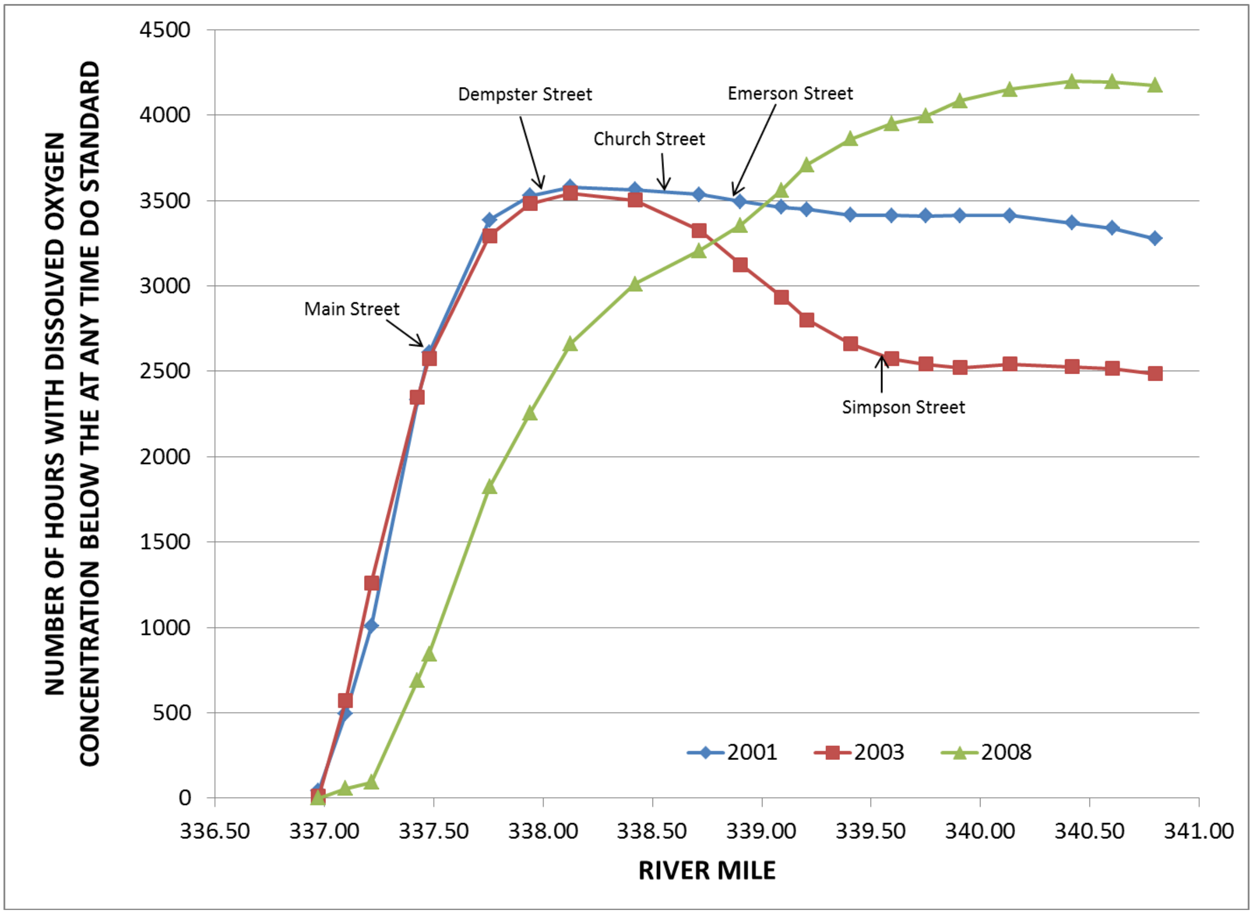

Figure 2.1. The number of hours at various locations on the North Shore Channel upstream of the O'Brien Water Reclamation Plant not attaining the at any time dissolved oxygen standard for the case of no discretionary diversion at the Wilmette Pumping Station and actual combined sewer overflows for Water Years 2001, 2003, and 2008.

2.2.1 Evaluation Procedure

For each of the representative WYs the DUFLOW model was run for the case of no discretionary diversion at the WPS. The simulated DO concentrations at the computational point closest to the proposed DO monitoring location—Emerson Street, Church Street, or Main Street—then were studied. The periods during which the simulated DO concentration was less than the at any time DO standard plus 0.3 mg/L then were identified. Discretionary diversion of 49 cfs was applied to these periods (no discretionary diversion was taken during the periods of flow reversal to Lake Michigan during WYs 2001 and 2008). The simulated DO concentrations resulting for the first allocation of discretionary diversion at the WPS then was studied. The periods for which the simulated DO concentration was less than the at any time DO standard plus 0.2 mg/L then were identified. Discretionary diversion of 100 cfs then was applied to these periods.

A review of measured DO concentrations at Linden Street (near the WPS) was done by Melching and Liang (2013) for days when discretionary diversion or navigation make-up water was taken, i.e. conditions at Linden Street were dominated by Lake Michigan water. Typically, when the conditions at the Linden Street DO monitor were dominated by Lake Michigan water, the DO concentrations ranged from about 85% of saturation to a little above saturation. Melching and Liang (2013) found that overall 95% of saturation seemed to give the best estimate of DO concentrations on days with discretionary diversion. Thus, for the periods when discretionary diversion is withdrawn at the WPS for WYs 2001 and 2003 the DO concentration assigned to these flows is the maximum of the measured DO concentration and 95% of saturation. For WY 2008 no measured DO concentrations were available, thus, 95% of saturation was applied during periods of discretionary diversion withdrawal and the DO concentrations estimated by Melching and Liang (2013) were applied in the periods without discretionary diversion.

2.2.2. Results

The performance of using the various DO monitoring locations to trigger the withdrawal of discretionary diversion was evaluated by determining the percentage of attainment of the at any time DO standard at Simpson Street and Main Street for each of the test water years. Tables 2.1-

2.3 list the percentage of attainment of the at any time DO standard achieved using each of the DO monitoring locations for WYs 2001, 2003, and 2008, respectively. Tables 2.1-2.3 also include the results for a scenario where periods of low DO at both Simpson Street and Main Street were used to identify when discretionary diversion is needed.

Table 2.1. Percentage of time attaining the at any time dissolved oxygen standard at Simpson Street and Main Street for the various possible DO monitoring locations for Water Year 2001.

Monitoring Location	Simpson Street	Main Street
Emerson Street	98.85	94.83
Church Street	98.76	95.38
Main Street	94.32	96.93
Simpson Street and Main Street	98.94	97.28

Table 2.2. Percentage of time attaining the at any time dissolved oxygen standard at Simpson Street and Main Street for the various possible DO monitoring locations for Water Year 2003.

Monitoring Location	Simpson Street	Main Street
Emerson Street	99.77	95.23
Church Street	99.70	96.27
Main Street	97.78	97.56
Simpson Street and Main Street	99.81	98.07

Table 2.3. Percentage of time attaining the at any time dissolved oxygen standard at Simpson Street and Main Street for the various possible DO monitoring locations for Water Year 2008.

Monitoring Location	Simpson Street	Main Street
Emerson Street	99.41	98.68
Church Street	97.81	98.66
Main Street	89.04	98.65
Simpson Street and Main Street	99.45	98.72

Having the DO monitor at Emerson Street or Church Street yielded nearly identical attainment of the at any time DO standard at Simpson Street as obtained using monitors at both Simpson Street and Main Street for WYs 2001 and 2003 and very high attainment of the at all times DO standards for WY 2008. However, using DO monitors at Emerson Street or Church Street resulted in attainment of the at any time DO standard being 2 to 3 percentage points lower at Main Street than using a DO monitor at Main Street or DO monitors at Simpson Street and Main Street for WYs 2001 and 2003. For WY 2008 the attainment of the at any time DO standard is similar for any of the DO monitor locations.

Having the DO monitor at Main Street yielded nearly identical attainment of the at any time DO standard at Main Street as using monitors at both Simpson Street and Main Street for WY 2008 and very similar attainment of the at any time DO standard for WYs 2001 and 2003. However, using a DO monitor at Main Street resulted in the attainment of the at any time DO standard being 2 to 4.5 percentage points lower at Simpson Street than using a DO monitor at Emerson Street or Church Street or DO monitors at Simpson Street and Main Street for WYs 2001 and 2003. For WY 2008 using a DO monitor at Main Street resulted in the attainment of the at any time DO standard being 8 to 10 percentage points lower at Simpson Street than obtained for DO monitors at Emerson Street, Church Street, or Simpson Street and Main Street. This poor performance for WY 2008 indicates that Main Street alone may not be an acceptable location for a DO monitor to control discretionary diversion withdrawal at the WPS.

Figures 2.2-2.4 show the simulated DO concentrations at Simpson Street for WYs 2001, 2003, and 2008, respectively, for the case of discretionary diversion withdrawn as per periods of low DO concentrations at DO monitors at Emerson Street, Church Street, and Main Street. Figures 2.5-2.7 show the simulated DO concentrations at Main Street for WYs 2001, 2003, and 2008, respectively, for the case of discretionary diversion withdrawn as per periods of low DO concentrations at DO monitors at Emerson Street, Church Street, and Main Street. From these figures it can be seen that having the DO monitor at Emerson Street or Church Street generally results in similar DO concentrations at both Simpson Street and at Main Street. As would be expected having the DO monitor at Main Street generally yields good DO concentrations at Main Street, with excursions below the at any time DO standard only resulting during storm periods. Having the DO monitor at Main Street generally yields good DO concentrations at Simpson Street for WYs 2001 and 2003, but lower attainment of the at any time DO standard in WY 2008.

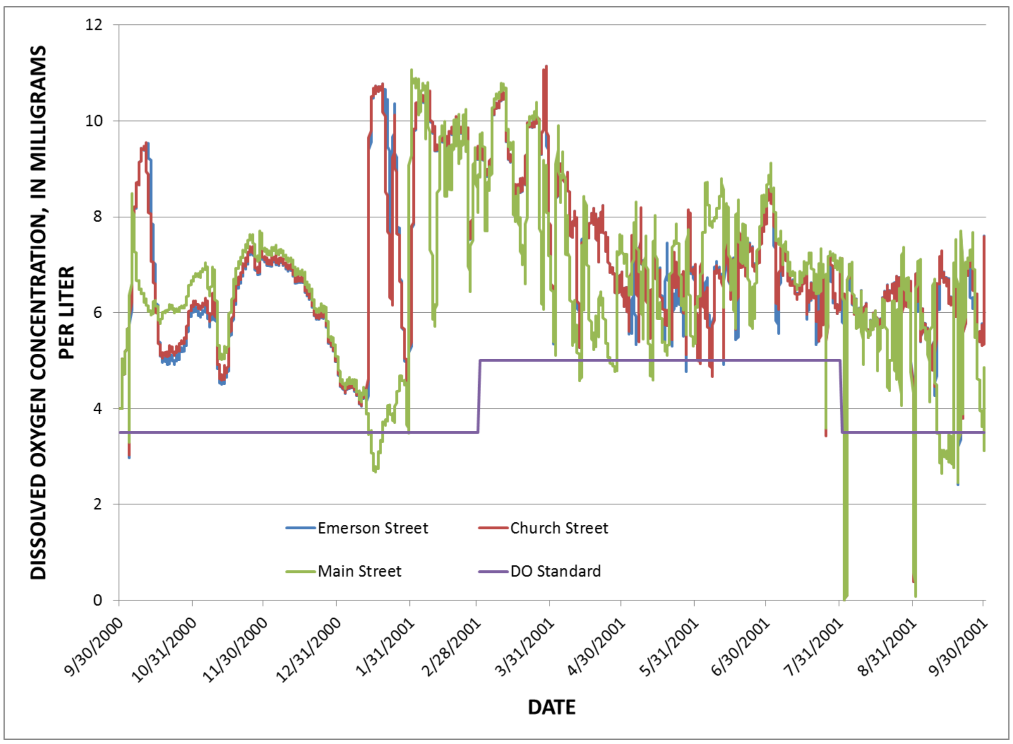

Figure 2.2. Simulated dissolved oxygen (DO) concentrations at Simpson Street for cases when discretionary diversion is withdrawn as per periods of low DO at proposed monitors at Emerson Street, Church Street, and Main Street for Water Year 2001.

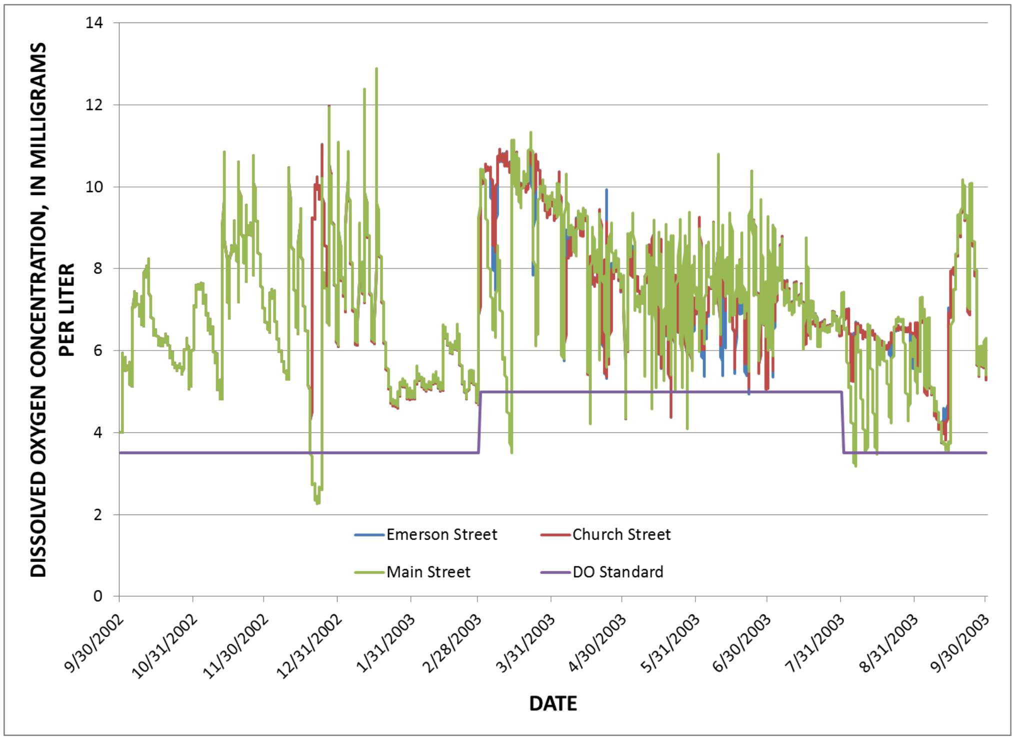

Figure 2.3. Simulated dissolved oxygen (DO) concentrations at Simpson Street for cases when discretionary diversion is withdrawn as per periods of low DO at proposed monitors at Emerson Street, Church Street, and Main Street for Water Year 2003.

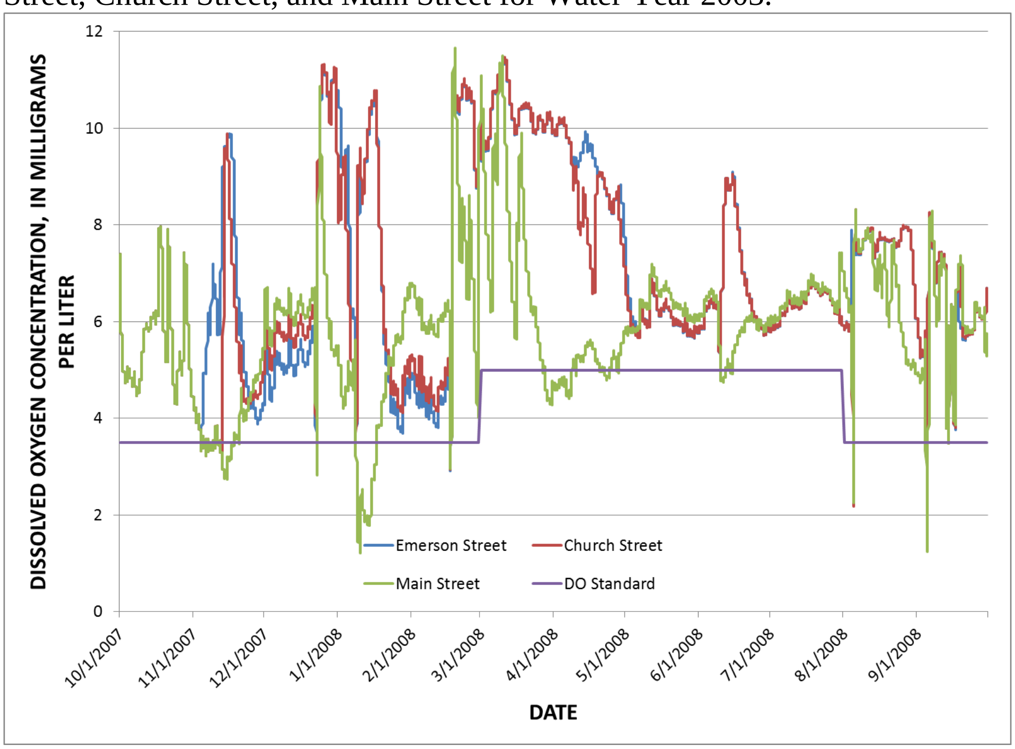

Figure 2.4. Simulated dissolved oxygen (DO) concentrations at Simpson Street for cases when discretionary diversion is withdrawn as per periods of low DO at proposed monitors at Emerson Street, Church Street, and Main Street for Water Year 2008.

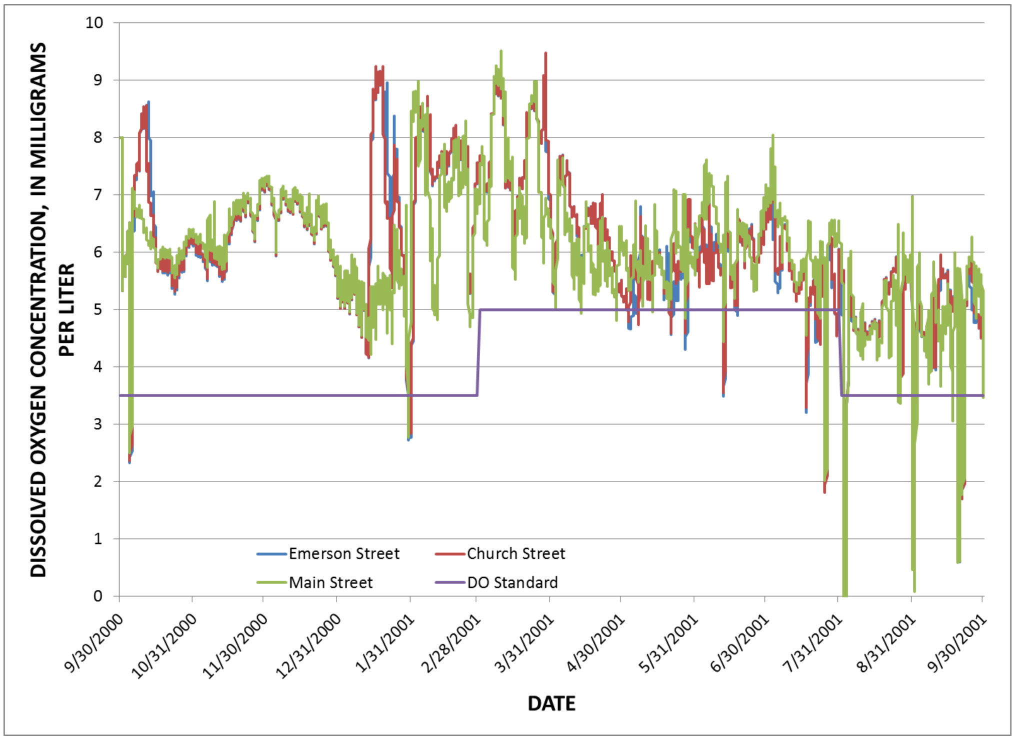

Figure 2.5. Simulated dissolved oxygen (DO) concentrations at Main Street for cases when discretionary diversion is withdrawn as per periods of low DO at proposed monitors at Emerson Street, Church Street, and Main Street for Water Year 2001.

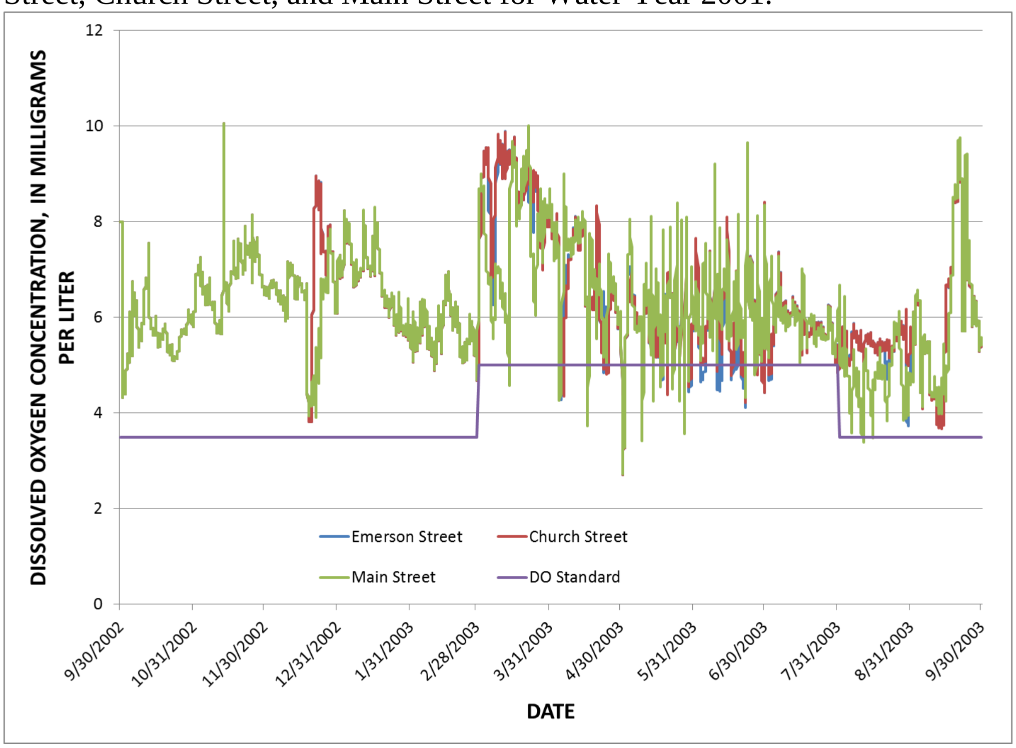

Figure 2.6. Simulated dissolved oxygen (DO) concentrations at Main Street for cases when discretionary diversion is withdrawn as per periods of low DO at proposed monitors at Emerson Street, Church Street, and Main Street for Water Year 2003.

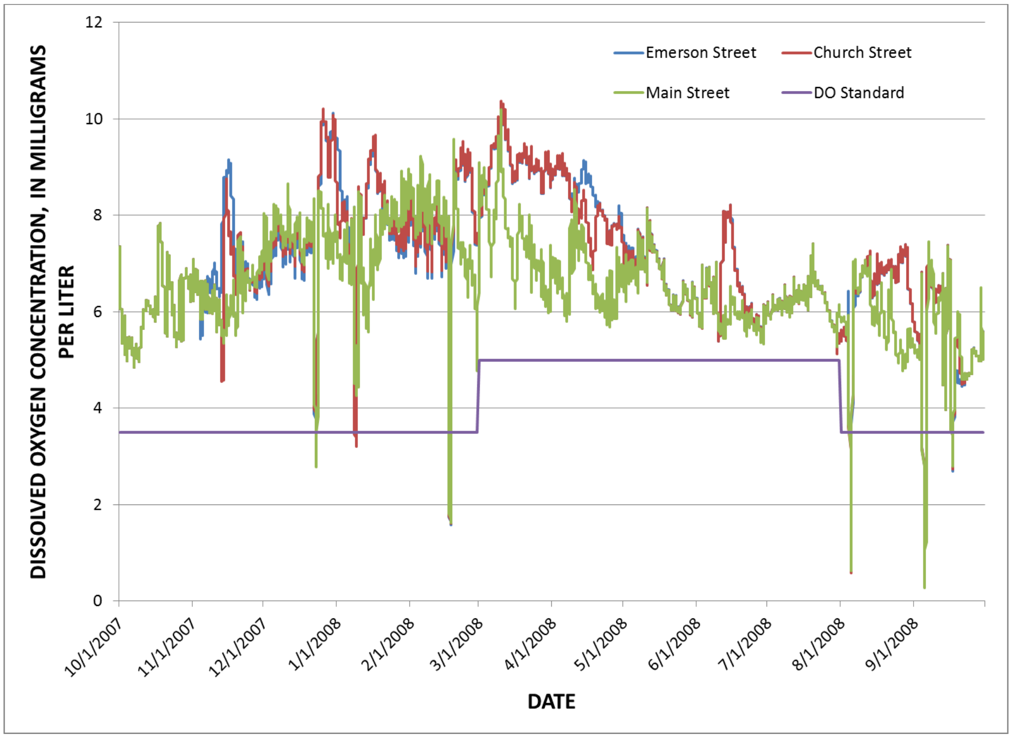

Figure 2.7. Simulated dissolved oxygen (DO) concentrations at Main Street for cases when discretionary diversion is withdrawn as per periods of low DO at proposed monitors at Emerson Street, Church Street, and Main Street for Water Year 2008.

In summary, taking discretionary diversion based on periods of low DO concentrations at DO monitors at Emerson Street or Church Street resulted in attainment of the at any time DO standard 94 percent of the time or greater at both Simpson Street and Main Street and similarly high percentages throughout the NSC upstream of the O'Brien WRP for all three representative WYs. However, some periods of low DO concentrations at Main Street were missed using only monitors at Emerson Street or Church Street. Thus, the MWRDGC decided to maintain the DO monitor at Main Street and to install a DO monitor at Emerson Street or Church Street. Initially, the MWRDGC thought Emerson Street would be the best location and so Part 1 on the project used DO monitors at Emerson Street and Main Street to determine the discretionary diversion withdrawal which is combined with IAS operations in the next section. However, it was later determined that Church Street would provide the best installation location for the upstream DO monitor, and so the results from Part 2 of the project reported in Chapters 4 and 5 and the final guidelines in Chapter 6 consider DO monitors at Church Street and Main Street on the NSC.

2.3 Operational Guidance for the Devon Avenue and Webster Avenue In-stream Aeration Stations

2.3.1 Background

The current operational protocol for the Devon Avenue and Webster Avenue IASs is based on DO concentrations measured at the North Branch Pumping Station (NBPS) 1.9 miles downstream from the Devon Avenue IAS and Ohio Street 2.9 miles downstream from the Webster Avenue IAS. The blowers at each IAS are operated based on DO concentrations observed at the NBPS or Ohio Street, as appropriate, as follows:

1) All blowers are off whenever DO concentrations are greater than 5.5 mg/L (i.e. 1.5 mg/L above the previous DO standard [i.e. prior to IPCB (2015)] for the NSC and NBCR downstream from the O'Brien WRP).
2) Start one blower if the DO concentration falls below 5.5 mg/L and leave it on until the DO concentration is above 5.5 mg/L, but at least 2 hours.
3) Start a second blower if the DO concentration falls below 5.0 mg/L and leave it on until the DO concentration is above 5.0 mg/L, but at least 2 hours.
4) Put on a third blower if the DO concentration falls below 4.5 mg/L and leave it on until the DO concentration is above 4.5 mg/L, but at least 2 hours.

The Devon Avenue IAS also is operated to supplement the Webster Avenue IAS in improving DO concentrations downstream on the NBCR at Ohio Street. This supplemental operation of the Devon Avenue IAS occurs any time three blowers are required at the Webster Avenue IAS, and consists of the following modified blower operation at the Devon Avenue IAS:

1) If DO concentration at the NBPS is less than 7.5 mg/L, run one blower.
2) If DO concentration at the NBPS is less than 6.5 mg/L, run two blowers.
3) If DO concentration at the NBPS is less than 6.0 mg/L, run three blowers.

The study to evaluate the possible relocation of the Devon Avenue IAS (Melching, 2014) found that the monitoring point for the operation of the Devon Avenue IAS should be moved from the NBPS to Fullerton Avenue. Further, once the monitoring point is changed there will be no need to operate the Devon Avenue IAS to supplement the operations of the Webster Avenue IAS. In the study of the possible relocation of the Devon Avenue IAS, the proposed IAS operational procedure was similar to the current operational procedure for the Devon Avenue and Webster Avenue IASs considering the DO concentrations at the operational monitoring point except that the monitoring point was moved to Fullerton Avenue for the Devon Avenue IAS and Kinzie Street was used as a surrogate for the existing DO monitor at Ohio Street (0.2 miles upstream) and the target DO concentrations are based on the IPCB (2015) DO standards as follows:

1) All blowers are off whenever DO concentrations are at least 1.5 mg/L above the at any time DO standard (i.e. 5.0 mg/L for August to February and 6.5 mg/L for March through July).

2) Start one blower if the DO concentration falls below 1.5 mg/L above the at any time DO standard (i.e. 5.0 mg/L for August to February and 6.5 mg/L for March through July) and leave it on until the DO concentration is greater than 1.5 mg/L above the DO standard.
3) Start a second blower if the DO concentration falls below 1.0 mg/L above the at any time DO standard (i.e. 4.5 mg/L for August to February and 6.0 mg/L for March through July) and leave it on until the DO concentration is greater than 1.0 mg/L above the DO standard.
4) Put on a third blower if the DO concentration falls below 0.5 mg/L above the at any time DO standard (i.e. 4.0 mg/L for August to February and 5.5 mg/L for March through July) and leave it on until the DO concentration is greater than 0.5 mg/L above the DO standard.

In the simulations, the following steps were followed to determine the operations of the various IASs. First, a run was made with the Devon Avenue and Webster Avenue IASs turned off. The DO concentration results of this run at Fullerton Avenue then were examined to determine the periods for which one blower should be turned on (i.e. periods with DO concentrations less than 5.0 mg/L in August through February and less than 6.5 mg/L in March through July). The DO load for the IAS then was computed based on the relations derived by Polls et al. (1982) for the case of one blower on considering the DO concentration and flow upstream of the IAS as explained later. The DO load was then added to the model at the IAS, and a new run was made. The DO concentration results of this second run at Fullerton Avenue then were examined to determine the periods for which two blowers should be turned on (i.e. periods with DO concentrations less than 4.5 mg/L in August through February and less than 6.0 mg/L in March through July). The DO load for the IAS then was computed based on the relations derived by Polls et al. (1982) for the cases of one or two blowers on as appropriate. The revised DO load was then added to the model at the IAS, and a new run was made. The DO concentration results of this third run at Fullerton Avenue then were examined to determine the periods for which three blowers should be turned on (i.e. periods with DO concentrations less than 4.0 mg/L in August through February and less than 5.5 mg/L in March through July). The DO load for the IAS then was computed based on the relations derived by Polls et al. (1982) for the cases of one, two, or three blowers on as appropriate. The revised DO load was then added to the model at the IAS, and a new run was made. The DO concentration results of this fourth run at Fullerton Avenue then were used to adjust the DO load delivered by the Webster Avenue IAS following the same step-by-step procedure as for the Devon Avenue IAS using Kinzie Street as a surrogate for the existing DO monitor at Ohio Street. The revised DO load for the Webster Avenue IAS then was input to the model, and the final DO concentrations throughout the NSC and NBCR downstream of the O'Brien WRP were obtained and the number of hours attaining the at any time DO standard at various locations along the NSC and NBCR was determined.

The previous study of the possible relocation of the Devon Avenue IAS (Melching, 2014) found that for the simulated DO concentrations at Fullerton Avenue for WYs 2001 and 2003 there were many cases of simulated DO concentrations getting within 1.5 or 1.0 mg/L of the DO standard but as the simulation proceeded for these periods the DO concentration really did not get close to the actual DO standard. Thus, a study to determine more appropriate operational rules for when to turn on one, two, or three blowers such that high attainment of the at any time DO standard can be achieved with a minimum amount of operational blower hours was done for each IAS as reported in the following subsections. Specifically, different operational rules for the Devon Avenue and Webster Avenue IASs were evaluated to determine rules that will yield high attainment of the at any time DO standard for the NSC and NBCR at a reduced amount of blower operations compared to the trial operational rules considered in the evaluation of the possible relocation of the Devon Avenue IAS (Melching, 2014). The evaluation was done for the two target WYs (2001 and 2003). Conditions for WY 2008 also were considered, but because the simulations for this year indicated extremely high attainment of the DO standards even for the case of the Devon Avenue and Webster Avenue IASs turned off, this year did not present a rigorous evaluation of the possible changes in IAS operation rules. Finally, in this evaluation the same set of operational rules were applied at each of the IASs for each evaluation.

2.3.2 Proposed Operational Rules

Table 2.4 lists the operational rules for the IASs evaluated in this study. As described previously, the rules are applied step-by-step in the simulations. That is, periods requiring one blower are determined from the simulation with no blowers on, then periods requiring two blowers are determined from the simulation with one blower on, and, finally, periods requiring three blowers are determined from the simulation with two blowers on. Further, the full operations for the Devon Avenue IAS are determined first, and then the operations for the Webster Avenue IAS are determined. It should be noted that this procedure results in an overestimate of the amount of time that different numbers of blowers will need to be in operation. This is because in actual operations once a blower is turned on the time required to return to the “on-off” DO level will be shortened compared to the previous simulation with one less blower in operation. This overestimation of the operational times will be similar for all potential operational rules for the IASs, and, thus, the overestimation will not affect the comparison among the different operational rules.

Table 2.4. Operational rules for the Instream Aeration Stations evaluated in this study. (note: Standard = the at any time dissolved oxygen standard).

Rule	1 Blower On	2 Blowers On	3 Blowers On
1	DO < Standard + 1.5 mg/L	DO < Standard + 1.0 mg/L	DO < Standard + 0.5 mg/L
2	DO < Standard + 1.2 mg/L	DO < Standard + 0.8 mg/L	DO < Standard + 0.4 mg/L
3	DO < Standard + 1.0 mg/L	DO < Standard + 0.7 mg/L	DO < Standard + 0.3 mg/L
4	DO < Standard + 1.0 mg/L	DO < Standard + 0.6 mg/L	DO < Standard + 0.3 mg/L
5	DO < Standard + 0.9 mg/L	DO < Standard + 0.6 mg/L	DO < Standard + 0.3 mg/L
6	DO < Standard + 0.75 mg/L	DO < Standard + 0.5 mg/L	DO < Standard + 0.25 mg/L

2.3.3 Dissolved Oxygen Loads at the Instream Aeration Stations

Equations describing the effects of upstream DO saturation on downstream DO absorption with different numbers of blowers in operation are given below after Polls et al. (1982):

$\%DO_{increase} = -0.455 * DO_{saturation} + 61.75$ (3 blowers in operation)

$\%DO_{increase} = -1.048 * DO_{saturation} + 96.42$ (2 blowers in operation)

$\%DO_{increase} = -0.516 * DO_{saturation} + 45.57$ (1 blower in operation)

where:

$\%DO_{increase}$ = Percent DO increase - 0.30 miles downstream of the aeration station at Lincoln Avenue

$DO_{saturation}$ = Percent DO saturation – upstream of the aeration station at Devon Avenue

The DO saturation concentration was determined using measured or estimated temperatures at Devon Avenue. Measured hourly temperatures were available at Devon Avenue through January 18, 2001. For all other periods the daily temperature was estimated using a flow weighted mass balance of the measured temperatures in the O'Brien WRP effluent and at Main Street on the NSC. The percent DO saturation then was determined from the ratio of the simulated DO concentration at Devon Avenue and the DO saturation concentration.

Although the regression equations were developed for the Devon Avenue IAS, in all the previous modeling studies for the MWRDGC (e.g., Alp and Melching, 2004, 2006; Neugebauer and Melching, 2005; Melching et al., 2010) it was assumed that they also are valid for the Webster Street IAS. Measured or estimated temperature and simulated DO concentration at Fullerton Avenue were used to define the upstream conditions for the Webster Avenue IAS.

The following equation is used to calculate DO load for input to the model:

$Load = \%DO_{increase} * DO_{upstream} * Q/100$

where:

Load = DO load from the IAS (g/s)

$\%DO_{increase}$ = Percent DO increase downstream of the aeration station from the foregoing regression equations

$DO_{upstream}$ = Simulated DO concentration for the computational point immediately upstream of the aeration station (mg/L)

Q = Simulated discharge at the computational point immediately upstream of the aeration station (m^3/s)

2.3.4 Results

Tables 2.5 and 2.6 list the number of hours that different numbers of blowers are on, the total number of blower hours, and the percent reduction in blower hours in comparison to Rule 1 for WYs 2001, 2003, and 2008 for the Devon Avenue and Webster Avenue IASs, respectively, under the various operational rules. Figure 2.8 shows the total number of blower hours for WYs 2001, 2003, and 2008 for the Devon Avenue and Webster Avenue IASs under the various operational rules. Table 2.7 lists the number of hours that do not attain the at any time DO standard at the Foster Avenue, Addison Street, Fullerton Avenue, Division Street, and Kinzie Street monitoring sites for WYs 2001, 2003, and 2008 under the various operational rules. Comparing the results for WYs 2001 and 2003 in Tables 2.5 and 2.6 with those in Table 2.7 it can be seen that reductions in the total number of blower hours on the order of 20 to 30% result in only very small increases in the number of hours not attaining the at any time DO standard. In fact, for Foster Avenue and Addison Street the reduced blower operations have almost no effect on the attainment of the at any time DO standard.

The ability to attain the at any time DO standard is most affected by changes in operation rules (total number of blower hours) at Fullerton Avenue. Figure 2.9 shows the increase in the number of hours not attaining the at any time DO standard at Fullerton Avenue for Operation Rules 2-6 compared to Operation Rule 1 for WYs 2001 and 2003. Figure 2.9 shows that Operational Rule 6 results in too large of an increase in the number of hours not attaining the at any time DO standard especially for WY 2003. Figure 2.8 shows that the largest reduction in blower hours occurs between Operational Rules 1 and 3 with only minor decreases in blower hours between Operational Rules 3 and 5. Thus, Operational Rule 3 seems to give and good balance between reduced blower operations and high attainment of the at any time DO standard. Further, selecting this relatively more conservative operational protocol compared to Operation Rules 4-6 provides a safety factor to account for modeling uncertainties and inaccuracies.

Table 2.5. Number of hours that different numbers of blowers are on, the total number of blower hours, and the percent reduction in blower hours in comparison to Rule 1 for Water Years 2001, 2003, and 2008 for the Devon Avenue Instream Aeration Station under the various operational rules

Rule	One Blower	Two Blowers	Three Blowers	Blower Hours	Percent Reduction in Blower Hours
2001					
1	2017	1307	740	6851	
2	1322	1174	639	5587	18.4
3	1046	1145	565	5031	26.6
4	1202	977	584	4908	28.4
5	1019	980	587	4740	30.8
6	865	926	563	4406	35.7
2003					
1	2020	2085	1271	10003	
2	1694	1880	1124	8826	11.8
3	1388	1869	996	8114	18.9
4	1608	1633	1012	7910	20.9
5	1448	1650	1013	7887	22.2
6	1354	1589	896	7220	27.8
2008					
1	1460	574	88	2818	
2	957	416	57	1960	30.4
3	630	351	49	1479	47.5
4	705	273	52	1407	50.1
5	506	279	52	1220	56.7
6	377	183	62	929	67.0

Table 2.6. Number of hours that different numbers of blowers are on, the total number of blower hours, and the percent reduction in blower hours in comparison to Operational Rule 1 for Water Years 2001, 2003, and 2008 for the Webster Avenue Instream Aeration Station under the various operational rules

Rule	One Blower	Two Blowers	Three Blowers	Blower Hours	Percent Reduction in Blower Hours
			2001		
1	3663	1264	131	6584	
2	3446	966	93	5657	14.1
3	3079	833	84	4997	24.1
4	3285	642	91	4842	26.5
5	2961	654	91	4269	35.2
6	2670	591	95	4137	37.2
			2003		
1	3883	1778	77	7670	
2	3490	1416	79	6559	14.5
3	3318	1237	81	6035	21.3
4	3580	990	81	5818	24.1
5	3357	1005	92	5643	26.4
6	3217	799	90	5085	33.7
			2008		
1	1938	171	17	2331	
2	1691	57	21	1868	19.9
3	1478	60	21	1661	28.7
4	1504	49	17	1653	29.1
5	1340	49	18	1492	36.0
6	1096	44	21	1247	46.5

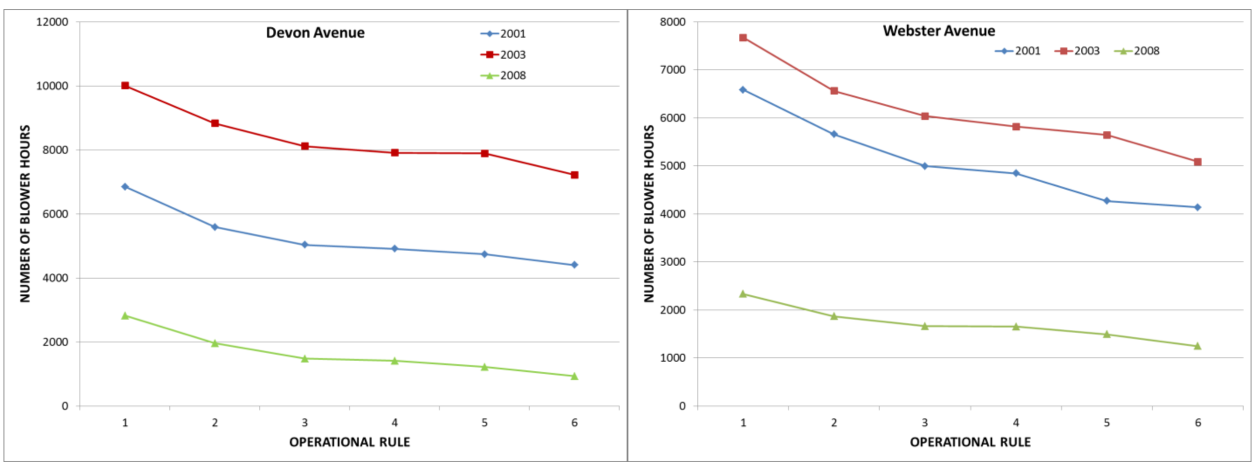

Figure 2.8. Total number of blower hours at the Devon Avenue and Webster Avenue instream aeration stations for Water Years 2001, 2003, and 2008 under the various operational rules

Table 2.7. Number of hours not attaining the at any time dissolved oxygen standard at monitoring locations on the North Shore Channel and North Branch Chicago River for Water Years 2001, 2003, and 2008 under the various operational rules

Rule	Foster Avenue	Addison Street	Fullerton Avenue	Division Street	Kinzie Street
			2001		
1	45	149	263	52	57
2	45	149	266	50	57
3	47	150	272	50	56
4	47	149	274	60	64
5	49	149	279	61	64
6	47	149	291	61	66
			2003		
1	22	110	164	20	19
2	22	110	180	21	20
3	22	108	187	26	22
4	22	108	203	26	26
5	22	108	204	26	30
6	22	111	223	31	40
			2008		
1	10	5	21	0	0
2	10	5	21	0	6
3	10	5	21	0	5
4	10	5	21	0	6
5	10	5	21	0	6
6	9	5	21	0	4

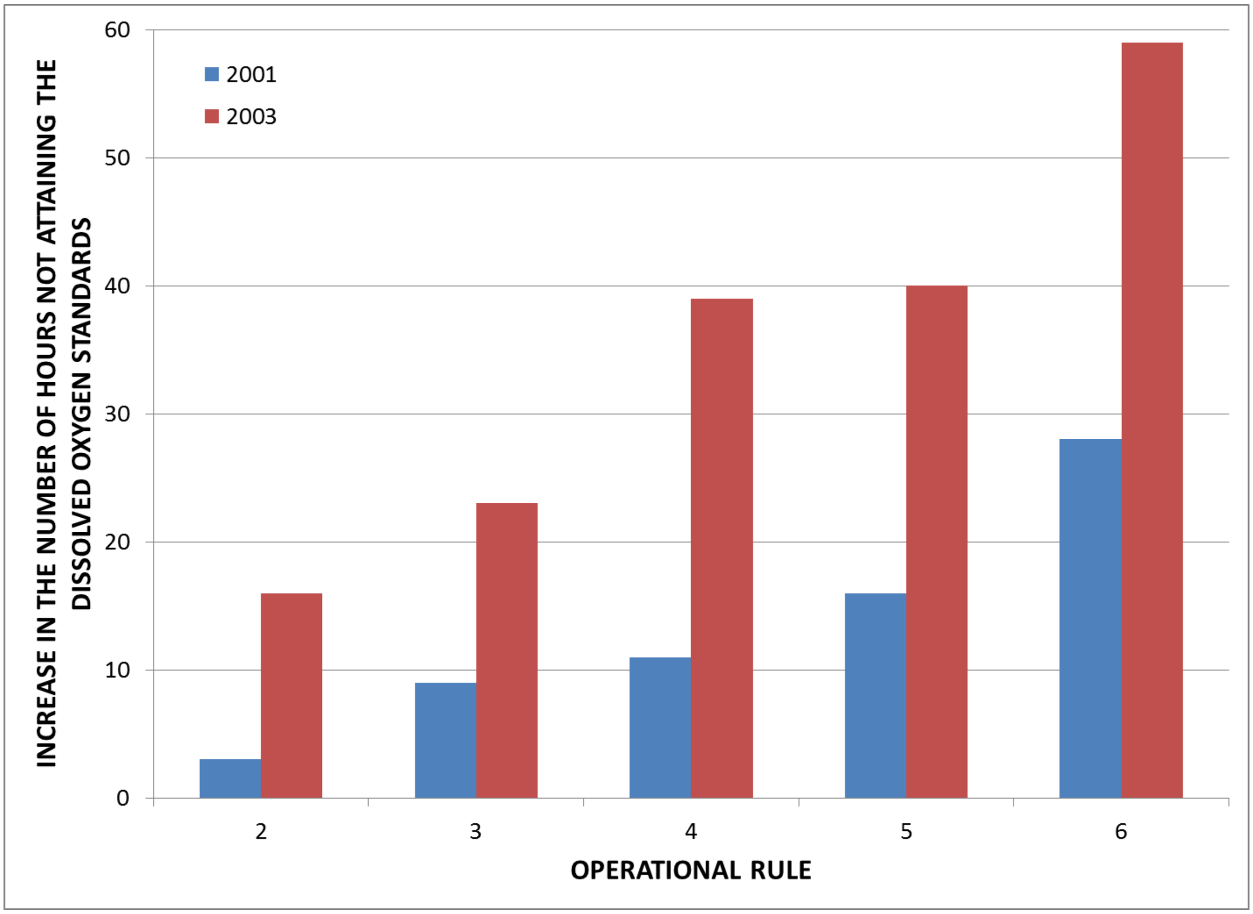

Figure 2.9. Increase in the number of hours not attaining the at any time dissolved oxygen standard at Fullerton Avenue compared to Operation Rule 1 under the various operational rules

2.3.5 Maximum Number of Blowers

Figure 2.10 shows the simulated DO concentrations at Fullerton Avenue for the cases of a maximum of 2 blowers turned on and a maximum of three blowers turned on for WYs 2001 and 2003. From this figure it can be seen that there is very little difference between the two simulation results. Similar results were obtained for WY 2008 and the Webster Avenue IAS. These results occur because the levels of DO saturation upstream of the Devon Avenue IAS are in the range where 2 blowers on and 3 blowers on yield similar DO loads according to the equations derived by Polls et al. (1982). Thus, under these conditions there is little environmental benefit to turning on the third blower, but substantial cost. Therefore, turning on a third blower is not recommended.

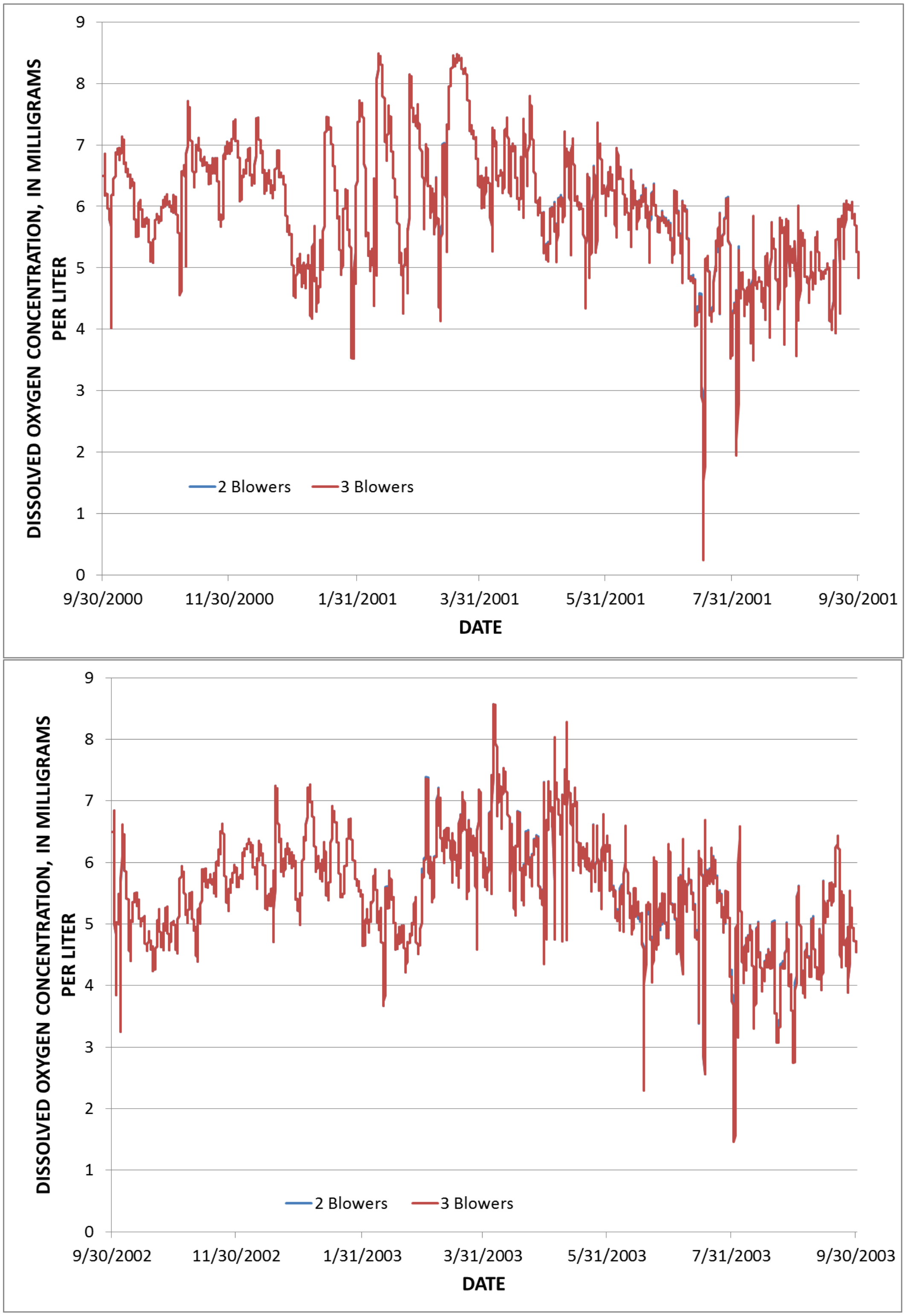

Figure 2.10. Simulated dissolved oxygen concentrations at Fullerton Avenue for the cases of a maximum of two blowers on and a maximum of three blowers on at Devon Avenue for Water Years 2001 and 2003.

The results of this study suggest the following Operational Rules for the Devon Avenue and Webster Avenue IASs, where the monitoring point for operation of the Devon Avenue IAS is Fullerton Avenue and the monitoring point for operation of the Webster Avenue IAS is Ohio Street, as follows:

1) All blowers are off whenever DO concentrations are at least 1.0 mg/L above the at any time DO standard (i.e. 4.5 mg/L for August to February and 6.0 mg/L for March through July).
2) Start one blower if the DO concentration falls below 1.0 mg/L above the at any time DO standard (i.e. 4.5 mg/L for August to February and 6.0 mg/L for March through July) and leave it on until the DO concentration is greater than 1.0 mg/L above the DO standard.
3) Start a second blower if the DO concentration falls below 0.7 mg/L above the at any time DO standard (i.e. 4.2 mg/L for August to February and 5.7 mg/L for March through July) and leave it on until the DO concentration is greater than 0.7 mg/L above the DO standard.

Chapter 3 Operational Guidance for the Little Calumet River (north) and Calumet-Sag Channel

3.1 Introduction

For the actual withdrawal of discretionary diversion at the O'Brien L&D and the actual operations of the SEPA stations the measured and simulated DO concentrations achieve high attainment of the DO standards throughout the Little Calumet River (north) and the Calumet-Sag Channel. Simulations have found that even for the case of no discretionary diversion at the O'Brien Lock and Dam the attainment of the at any time DO standard is high (greater than 95 percent at nearly all locations for WYs 2001, 2003, and 2008). The high level of attainment of the at any time DO standard even for the case of no discretionary diversion at the O'Brien Lock and Dam is the result of the nearly continuous operation of at least one pump at each SEPA station from early April to late October/early November each year. Thus, the purpose of the study reported here is to determine if guidelines for optimal withdrawal of discretionary diversion at the O'Brien L&D and operation of SEPA stations 2, 3, and 4 can be determined that will effectively achieve the same level of high attainment of the at any time DO standard, but with substantially reduced SEPA station operational hours and discretionary diversion at the O'Brien Lock and Dam compared to actual conditions in WYs 2001, 2003, and 2008.

As a starting point for the development of operational guidance for withdrawal of discretionary diversion at the O'Brien L&D and operation of SEPA stations 2, 3, and 4, a simulation was made for the case of no discretionary diversion at any of the lakefront locations and SEPA stations 2, 3, 4, and 5 turned off. The percentage of attainment of the at any time DO standard resulting for this simulation is shown in Figure 3.1 for WYs 2001, 2003, and 2008. Figure 3.1 shows that attainment less than 90% can occur at various locations along the Little Calumet River (north) and Calumet-Sag Channel without discretionary diversion and SEPA station operations. Thus, the results in Figure 3.1 clearly show that some level of discretionary diversion at the O'Brien L&D and SEPA station operations are needed to achieve attainment greater than 95% throughout the Little Calumet River (north) and Calumet-Sag Channel. The goal of this study is to define guidance for "optimal" withdrawal of discretionary diversion and operation of the SEPA stations to achieve such high levels of attainment of the DO standards.

3.2 Guidance for "Optimal" Discretionary Diversion at the O'Brien Lock and Dam

The procedure for determining guidance for "optimal" discretionary diversion at the O'Brien L&D starts with the simulation of DO concentrations in the CAWS for the case of no discretionary diversion at any of the lakefront structures and the SEPA stations turned off. For WYs 2001 and 2003, the daily discretionary diversion flows estimated by the MWRDGC were subtracted from the 15-min. flows measured by the USGS at the North Shore Channel at Maple Avenue (near the Wilmette Pumping Station), Chicago River at Columbus Drive (near the CRCW), and O'Brien L&D to determine the boundary flows for the case of no discretionary diversion. For WY 2008, the daily lockage, navigation make-up, and leakage flows at the lakefront structures estimated by the MWRDGC were used as the boundary flows for the case of no discretionary diversion. The results of these simulations will determine the periods for which discretionary diversion at the O'Brien L&D is needed to achieve high percentages of attainment of the at any time DO standard at locations on the Little Calumet River (north) upstream of the Calumet WRP.

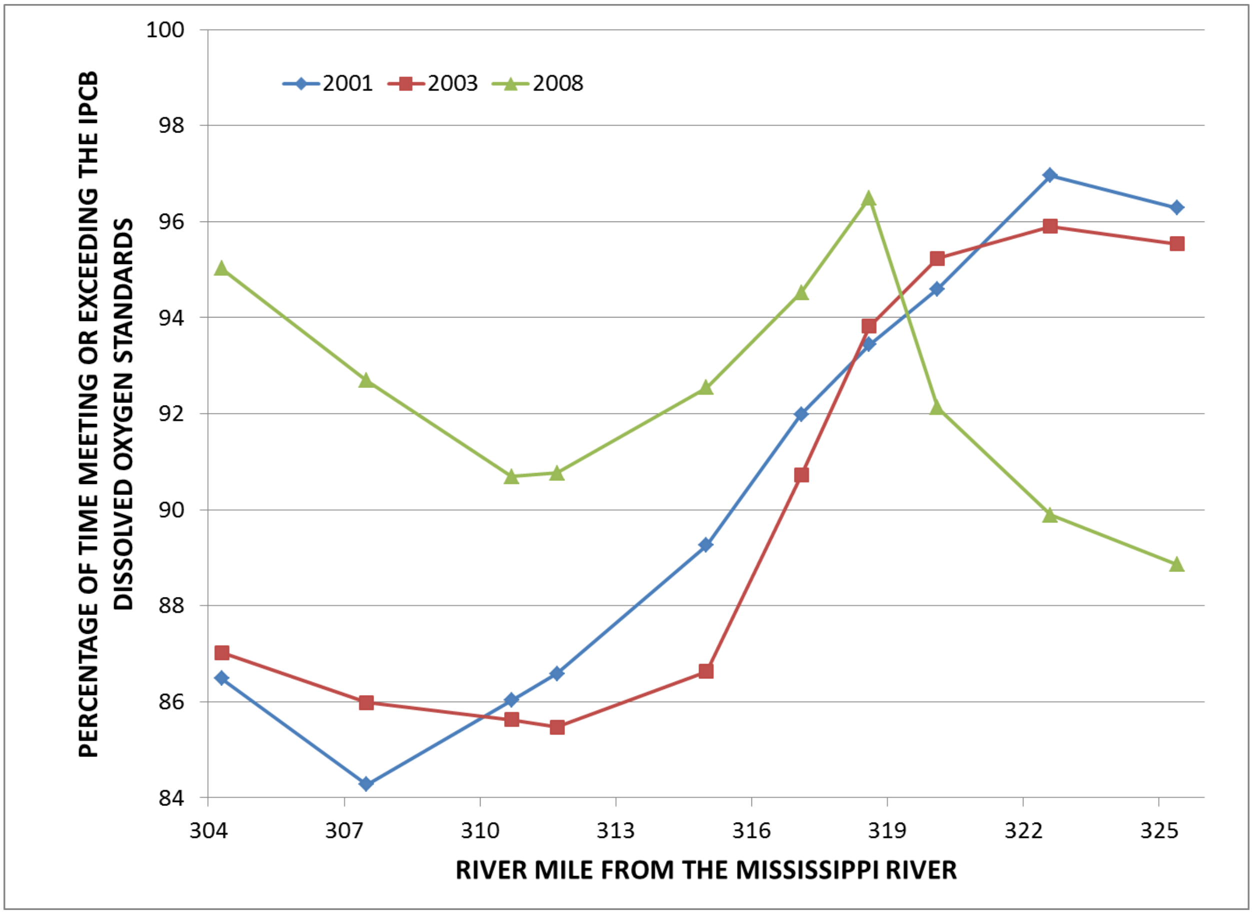

Figure 3.1. Percentage of time that simulated dissolved oxygen (DO) concentrations meet or exceed (i.e. attain) the at any time DO standard along the Little Calumet River (north) and Calumet-Sag Channel for the case of no discretionary diversion at the O'Brien Lock and Dam and the Sidestream Elevated Pool Aeration Stations shut down.

In order to remediate periods of low DO in the Little Calumet River (north) upstream of the Calumet WRP, these periods must be identified at a monitoring location on the Little Calumet River (north) that is close enough to the O'Brien Lock and Dam so that periods of low DO can be effectively counteracted as they are detected at the monitoring location. Table 3.1 lists the average travel time from the O'Brien Lock and Dam to various locations on the Little Calumet

River (north) and Calumet-Sag Channel. These average travel times were calculated from the flow velocities in the CAWS computed with the DUFLOW model for the period of July 1 to August 31, 2003. This period was chosen because it was a period with substantial discretionary diversion, which allows a reasonable estimate of travel times for periods with discretionary diversion in those reaches of the CAWS that do not convey treated effluent, such as the Little Calumet River (north) upstream of the Calumet WRP.

Table 3.1. Average travel times from the O'Brien Lock and Dam to points on the Little Calumet River (north) and Calumet-Sag Channel for the period July 1 to August 31, 2003.

Location	River Mile	Waterway	Travel Time (hr)
Conrail Railroad	325.4	Little Calumet River (north)	24.5
Central & Wisconsin Railroad	322.6	Little Calumet River (north)	59.0
Halsted Street	320.1	Little Calumet River (north)	94.7
Calumet-Sag Channel begin	319.6	Little Calumet River (north)	97.6
Division Street	318.6	Calumet-Sag Channel	101.7
Kedzie Street	317.1	Calumet-Sag Channel	107.7
Cicero Avenue	315.0	Calumet-Sag Channel	116.7
Harlem Avenue	311.7	Calumet-Sag Channel	130.1
Southwest Highway	310.7	Calumet-Sag Channel	133.8
104th Avenue	307.5	Calumet-Sag Channel	147.5
Route 83	304.3	Calumet-Sag Channel	161.9
Sag Junction	303.4	Calumet-Sag Channel	163.5

Previous studies have shown that discretionary diversion can be taken "On Demand" based on low DO concentrations for locations within about 1 day travel time of the diversion locations, i.e. up to Conrail Railroad on the Little Calumet River (north). Thus, Conrail Railroad was selected as the monitoring location and periods with simulated DO concentrations less than a tolerance value above the at any time DO standard were selected for the application of various amounts of discretionary diversion. Two tolerance values—0.5 and 0.3 mg/L—were tested in this study. Thus, the periods with DO concentrations at Conrail Railroad less than 4.0 mg/L for August through February and 5.5 mg/L for March through July were identified for application of discretionary diversion at the O'Brien L&D composing one set of potential discretionary diversion periods. Also, the periods with DO concentrations less than 3.8 mg/L for August through February and 5.3 mg/L for March through July were identified for application of discretionary diversion at the O'Brien L&D composing the second set of potential discretionary diversion periods. The amount of discretionary diversion applied to these periods was varied in 50 cfs increments and the change in attainment of the at any time DO standard at Conrail Railroad was evaluated.

Figure 3.2 shows that using the trigger of 0.3 mg/L above the DO standard to start the discretionary diversion yields effectively the same level of attainment of the at any time DO standard as the trigger of 0.5 mg/L above the standard. Using the trigger of 0.3 mg/L saved 17.1 to 22.2% of the discretionary diversion water required when using the trigger of 0.5 mg/L. Thus, to conserve discretionary diversion water for withdrawal at the WPS or CRCW the trigger of 0.3 mg/L above the at any time DO standard (i.e. 3.8 mg/L for August through February and 5.3 mg/L for March through July) at Conrail Railroad should be applied when taking discretionary diversion at the O'Brien L&D.

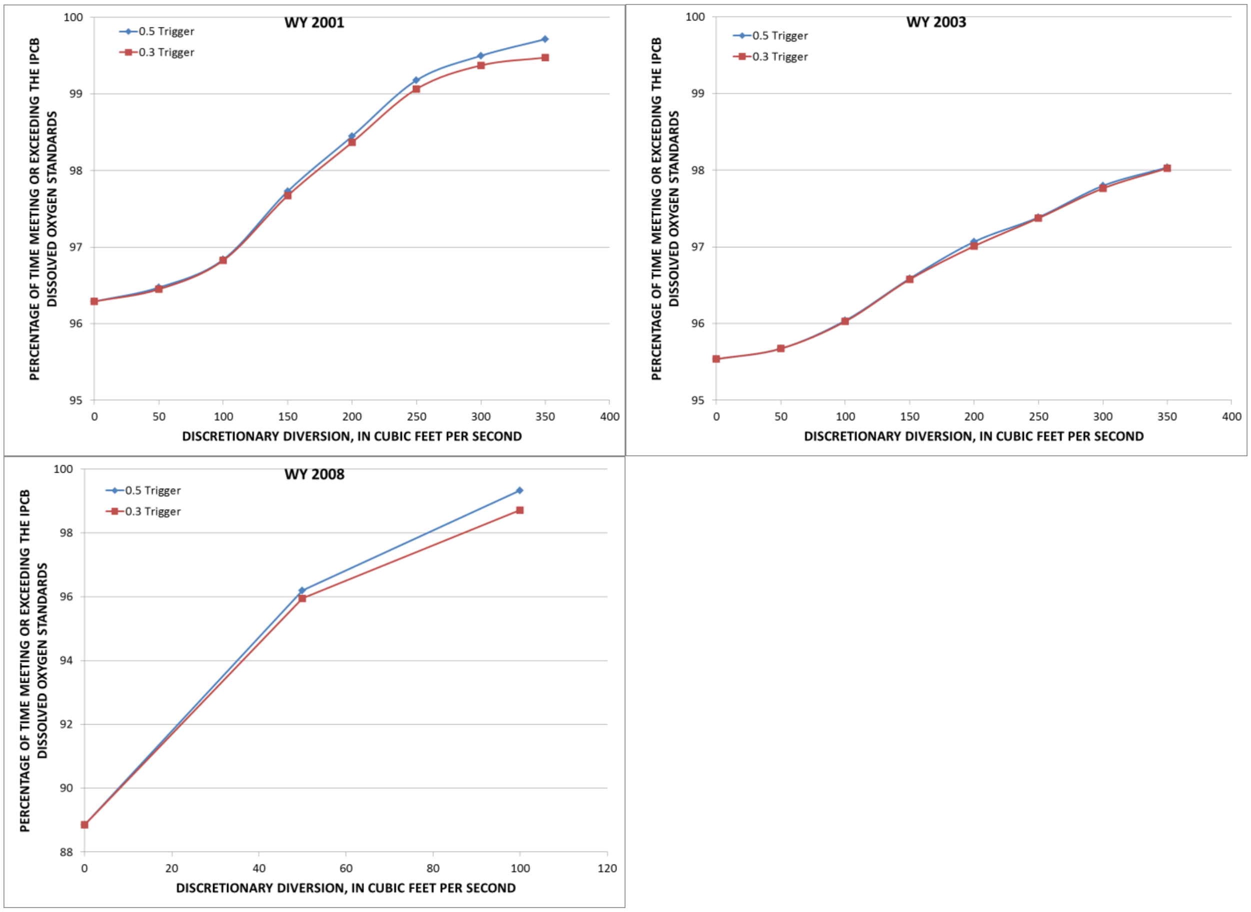

Figure 3.2. Percentage of time that simulated dissolved oxygen (DO) concentrations meet or exceed (i.e. attain) the at any time DO standard at Conrail Railroad on the Little Calumet River (north) for varying amounts of discretionary diversion at the O'Brien Lock and Dam and varying triggers to identify periods needing discretionary diversion.

Figure 3.3 shows the attainment of the at any time DO standard for the case of using a trigger of 0.3 mg/L above the DO standard at Conrail Railroad for WYs 2001, 2003, and 2008. From Figure 3.3 it can be seen that if a constant discretionary diversion of 100 cfs is taken at the O'Brien Lock and Dam for all periods at Conrail Railroad with simulated DO concentrations less than the at any time DO standard plus 0.3 mg/L, then the at any time DO standard can be attained greater than 96% of the time for all three WYs. Thus, the optimization of the SEPA station operations was done for the case of 100 cfs of discretionary diversion taken at the

O’Brien L&D for periods at Conrail Railroad with DO less than 3.8 mg/L in August through February and less than 5.3 mg/L in March through July.

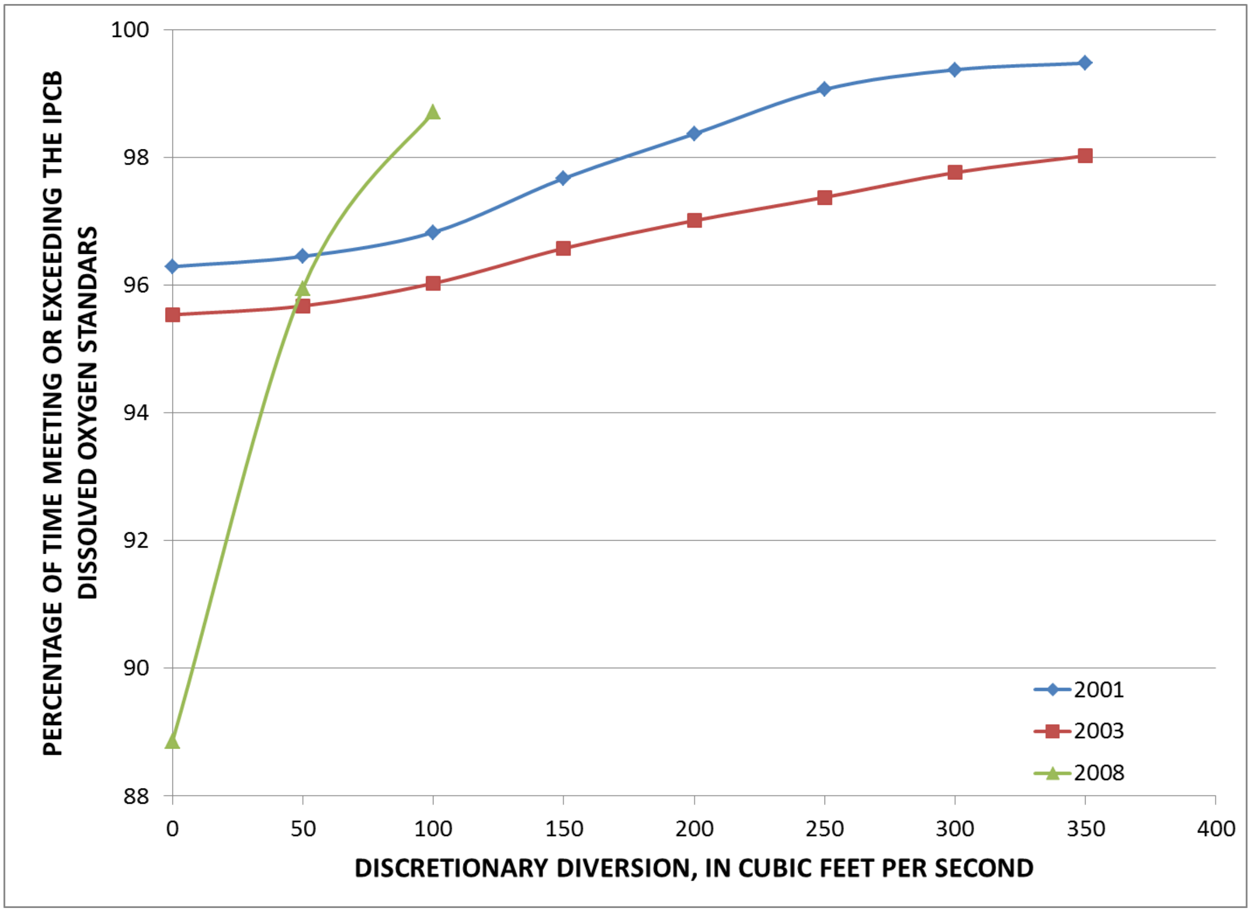

Figure 3.3. Percentage of time that simulated dissolved oxygen (DO) concentrations meet or exceed (i.e. attain) the at any time DO standard at Conrail Railroad on the Little Calumet River (north) for varying amounts of discretionary diversion at the O’Brien Lock and Dam.

3.3 Guidance for “Optimal” Operations of the Sidestream Elevated Pool Aeration Stations

As noted earlier, traditionally each of the SEPA stations has been turned on in early April and shut down in late October/early November each year unless maintenance and/or repairs caused a SEPA station to shut down for a longer period during the normal operation period (e.g., SEPA station 3 did not start until July 3 in 2001 and it shut down on September 3 in 2008). Table 3.2 lists the dates SEPA stations 2, 3, and 4 were turned on and off for each calendar year from 1998 to 2014.

Table 3.2. Operational periods for Sidestream Elevated Pool Aeration Stations 2, 3, and 4 for 1998 through 2014.

Calendar Year	SEPA 2		SEPA 3		SEPA 4	
	On	Off	On	Off	On	Off
1998	April 12	October 27	April 6	October 30	April 6	October 10
1999	April 1	October 31	April 1	October 31	April 1	November 2
2000	April 12	October 27	April 3	October 31	April 3	November 6
2001	April 12	October 30	July 1	November 7	April 10	November 5
2002	April 6	October 31	April 1	November 12	April 1	November 5
2003	April 1	November 3	April 1	November 4	April 1	November 9
2004	April 5	November 1	April 5	November 8	April 5	November 8
2005	April 8	October 31	April 8	October 31	April 8	October 31
2006	April 5	November 1	April 5	November 1	April 6	November 1
2007	April 2	November 9	April 2	November 6	April 2	October 26
2008	April 2	November 3	April 3	September 3	April 25	November 3
2009	April 1	November 2	May 1	November 2	April 1	November 2
2010	April 1	November 1	April 1	November 1	April 1	November 1
2011	April 1	November 4	April 1	November 1	April 1	November 3
2012	April 1	November 2	April 2	November 2	April 1	November 2
2013	April 5	November 1	April 4	November 1	April 3	November 1
2014	April 24	November 3	April 14	October 28	April 2	November 6

A question this study would like to answer is whether these longer periods of SEPA pump operations are truly needed to achieve the same high levels of attainment of the DO standards. Thus, this study develops and evaluates two sets of SEPA station operation protocols to compare the performance of "traditional" SEPA station operations to "optimal" SEPA station operations. For the "optimal" SEPA station operations pumps will only be turned on at the SEPA stations when a downstream DO monitor indicates DO concentrations are approaching the at any time DO standard. For the "modified traditional" SEPA station operations one pump will be turned on for the entire period of actual SEPA station operations for a given year with the modification that the period of operations at SEPA 3 is started at noon on April 1, 2001 and extended to midnight on September 30, 2008 to reflect the typical operation period for all years at SEPA 3. For each case the operation of a second pump depends on whether the simulated DO concentration continues to approach the at any time DO standard (i.e. within a second tolerance level) even if one pump is on, and the operation of a third pump depends on whether the simulated DO concentration continues to approach the at any time DO standard (i.e. within a third tolerance level) even if two pumps are on.

3.3.1 Calculation Procedure for SEPA Station Dissolved Oxygen Loads

In this study the procedure given by Alp and Melching (2004) for the DO loads from SEPA stations 3, 4, and 5, and extended by Melching and Liang (2013) to determine the DO load from SEPA 2 was applied. In this procedure, the oxygen load from the SEPA stations is calculated using the following formula:

$$\text{OXYGEN LOAD} = Q_P \times \alpha \times (C_{SAT} - C_{UPSTREAM})/1000 \text{ in kg/s}$$

where: Q_P = Flow through the SEPA station, m^3/s = number of pumps operating x pump capacity (pump capacity for SEPA 2 = 1.23 m^3/s, SEPA 3 and 4 = 3.39 m^3/s, and SEPA 5 = 3.27 m^3/s)

C_{SAT} = Saturation concentration of dissolved oxygen, mg/L, (determined from continuous in-stream temperature data)

$C_{UPSTREAM}$ = Dissolved oxygen concentration (mg/L) upstream of SEPA station from results of the previous modeling run

α = Fraction of saturation achieved = f(number of pumps in operation), from Butts et al. (1999).

The fraction of saturation achieved is listed in Table 3.3. These oxygen loads are directly input to the CAWS as a point source in the DUFLOW water-quality simulation.

Table 3.3. Fraction of dissolved oxygen saturation achieved by the Sidestream Elevated Pool Aeration (SEPA) stations with different pump operations (after Butts et al., 1999, 2000)

SEPA Station	**Number of Pumps**			
	1	**2**	**3**	**4**
2	0.99	0.99		
3	1.01	1.01	0.99	
4	1.01	1.05	1.02	
5	0.93	0.98	1.02	1.02

SEPA 5 is listed in Table 3.3, but its optimal operations were not evaluated in Part 1 of this study (which is reported in this chapter) because its optimal operations are dependent on conditions upstream on the CSSC that could not be determined until the total allowable discretionary diversion was set by the IDNR in September 2016 and the overall discretionary diversion in optimized. Details of the operation of SEPA 5 are given in Chapters 4-6.

3.3.2 SEPA 2 Operations

In the evaluation of "optimal" operations of the Devon Avenue and Webster Avenue IASs in Chapter 2, the use of Rule 5 in Table 2.4 with tolerance levels 0.9, 0.6, and 0.3 mg/L above the at any time DO standard yielded efficient and effective operation of 1, 2, and 3 blowers, respectively, at the IASs (although in the end Rule 3 is recommended). Therefore, a similar approach was proposed for the "optimal" SEPA station pump operations. For SEPA 2, there are only 2 pumps, thus, two different operational protocols were evaluated. In the first protocol, one pump was turned on if the simulated DO concentration at the monitoring point was less than 0.6 mg/L above the at any time DO standard (i.e. less than 4.1 mg/L for August through February and less than 5.6 mg/L for March through July) for the case of 100 cfs of discretionary diversion at selected times at the O'Brien L&D. The second pump would be turned on if the simulated DO concentration at the monitoring point continued to decrease to less than 0.3 mg/L above the at any time DO standard (i.e. less than 3.8 mg/L for August through February and less than 5.3 mg/L for March through July) for the case of 1 pump on at SEPA 2. In the second protocol, one pump was turned on if the simulated DO concentration at the monitoring point was less than 0.9 mg/L above the at any time DO standard (i.e. less than 4.4 mg/L for August through February and less than 5.9 mg/L for March through July) for the case of 100 cfs of discretionary diversion at selected times at the O'Brien L&D. The second pump would be turned on if the simulated DO concentration at the monitoring point continued to decrease to less than 0.6 mg/L above the at any time DO standard (i.e. less than 4.1 mg/L for August through February and less than 5.6 mg/L for March through July) for the case of 1 pump on at SEPA 2. The simulation results found no statistically significant improvement in attainment of the at any time DO standard for the second protocol compared to the first. Thus, the extra pump operation hours for the second protocol cannot be justified, and the first protocol is recommended for "optimal" operation of SEPA 2.

SEPA 2 is located at River Mile (RM) 321.3 on the Little Calumet River (north). Assuming the average flow velocity between SEPA 2 and Halsted Street is the same as that between Halsted Street and the Junction of the Little Calumet River and the Calumet-Sag Channel, the travel time between SEPA 2 and Division Street is approximately 14 hours making this a good DO monitoring location for the operation of SEPA 2. Thus, the proposed "optimal" operation protocol for SEPA 2 is as follows: when the DO concentration at Division Street on the Calumet-

Sag Channel is drops below 0.6 mg/L above the at any time DO standard (i.e. less than 4.1 mg/L for August through February and less than 5.6 mg/L for March through July) turn on one pump at SEPA 2, and this pump should remain on until the DO concentration exceeds 0.6 mg/L above the DO standard. If the DO concentration at Division Street continues to decrease to less than 0.3 mg/L above the at any time DO standard (i.e. less than 3.8 mg/L for August through February and less than 5.3 mg/L for March through July), the second pump should be turned on at SEPA 2, and this pump should remain on until the DO concentration exceeds 0.3 mg/L above the DO standard.

For the “modified traditional” operation of SEPA 2, one pump is turned on for all actual operational periods in the test years. If the DO concentration at Division Street drops below 0.3 mg/L above the at any time DO standard (i.e. less than 3.8 mg/L for August through February and less than 5.3 mg/L for March through July), the second pump should be turned on at SEPA 2, and this pump should remain on until the DO concentration exceeds 0.3 mg/L above the DO standard.

The “optimal” and “modified traditional” operation protocols were applied to SEPA 2 operations for each of WYs 2001, 2003, and 2008. Table 3.4 lists the pump operations determined for each of these schemes as well as the actual pump operations for SEPA 2 for each of the test years. As can be seen in Table 3.4, the “modified traditional” operations may result in a 0.6 to 19.1% increase in total pump hours compared to the actual operations. This increase represents, in part, the increase in the DO standards in this study compared to the DO standard of 3 mg/L at any time considered in the actual SEPA 2 operations in WYs 2001, 2003, and 2008. Also, as can be seen in Table 3.4, the "optimal" operations may result in a 45.2 to 86.6% decrease in total pump hours compared to actual operations. This decrease is even more impressive when the previously discussed increase in DO standards is considered. Finally, Table 3.4 indicates the "optimal" operations may result in a 54.0 to 86.7% decrease in total pump hours compared to "modified traditional" operations.

Table 3.4. Actual pump operations in hours compared with "optimal" and "modified traditional" pump operation protocols at Sidestream Elevated Pool Aeration Station 2 for Water Years 2001, 2003, and 2008.

Operational Scheme/Year	1 Pump	2 Pumps	Pump hours
2001			
Actual	4464	0	4464
Optimal	327	699	1725
Modified Traditional	3780	688	5156
2003			
Actual	4392	0	4392
Optimal	686	860	2406
Modified Traditional	3554	838	5230
2008			
Actual	5397	0	5397
Optimal	664	30	724
Modified Traditional	5371	28	5427

3.3.3 SEPA 3 Operations

SEPA 3 has 4 pumps, but only a maximum of 3 pumps will ever be used at one time with the fourth pump being held in reserve in case of maintenance needs. SEPA 3 is located at RM 318 on the Calumet-Sag Channel. Through linear interpolation of the travel times in Table 3.2 to the location of SEPA 3, the travel time between SEPA 3 and Cicero Avenue is approximately 12.6 hours making this a good DO monitoring location for the operation of SEPA 3. Thus, the proposed "optimal" operation protocol for SEPA 3 is as follows. When the DO concentration at Cicero Avenue on the Calumet-Sag Channel drops below 0.9 mg/L above the at any time DO standard (i.e. less than 4.4 mg/L for August through February and less than 5.9 mg/L for March through July) turn on one pump at SEPA 3, and this pump should remain on until the DO concentration exceeds 0.9 mg/L above the DO standard. If the DO concentration at Cicero Avenue continues to decrease to less than 0.6 mg/L above the at any time DO standard (i.e. less than 4.1 mg/L for August through February and less than 5.6 mg/L for March through July), a second pump should be turned on at SEPA 3, and this pump should remain on until the DO concentration exceeds 0.6 mg/L above the DO standard. Finally, if the DO concentration at Cicero Avenue continues to decrease to less than 0.3 mg/L above the at any time DO standard (i.e. less than 3.8 mg/L for August through February and less than 5.3 mg/L for March through July), a third pump should be turned on at SEPA 3, and this pump should remain on until the DO concentration exceeds 0.3 mg/L above the DO standard.

For the "modified traditional" operation of SEPA 3, one pump is turned on for all actual operational periods in the test years. These periods of one pump operations were extended from the actual operational hours to noon on April 1, 2001 (to compensate for the actual operations starting on July 3, 2001) and to midnight on September 30, 2008 (to compensate for the actual shut down on September 3) to reflect the typical operation period for all years at SEPA 3. If the DO concentration at Cicero Avenue drops below 0.6 mg/L above the at any time DO standard (i.e. less than 4.1 mg/L for August through February and less than 5.6 mg/L for March through July), a second pump should be turned on at SEPA 3, and this pump should remain on until the DO concentration exceeds 0.6 mg/L above the DO standard. If the DO concentration at Cicero Avenue decreases to less than 0.3 mg/L above the at any time DO standard (i.e. less than 3.8 mg/L for August through February and less than 5.3 mg/L for March through July), a third pump should be turned on at SEPA 3, and this pump should remain on until the DO concentration exceeds 0.3 mg/L above the DO standard.

The “optimal” and “modified traditional” operation schemes were applied to SEPA 3 operations for each of WYs 2001, 2003, and 2008. Table 3.5 lists the pump operations determined for each of these schemes as well as the actual pump operations for SEPA 3 for each of the test years. As can be seen in Table 3.5, the “modified traditional” operations resulted in a 22.8% reduction in total pump hours compared to actual operations in WY 2008 because of the large decrease in hours with 2 or 3 pumps on, further this reduction occurs even though SEPA 3 was shut down for nearly all of September 2008. On the other hand, the “modified traditional” operations resulted in a 28.7% increase in total pump hours compared to the actual operations in WY 2003. No comparison between “modified traditional” and actual operations can be made for SEPA 3 for WY 2001 because of the April through June shut down of SEPA 3 in actual operations. The increase in WY 2003 represents, in part, the increase in the DO standards in this study compared to the DO standard of 3 mg/L at any time considered in the actual SEPA 3 operations in WY 2003, whereas the decrease in WY 2008 occurs despite the increase in DO standards. Also, as can be seen in Table 3.5, the “optimal” operations may result in a 8.5 to 70.0% decrease in total pump hours compared to actual operations. This decrease is even more impressive when the previously discussed increase in DO standards is considered. Finally, Table 3.5 indicates the “optimal” operations may result in a 28.4 to 61.1% decrease in total pump hours compared to “modified traditional” operations.

Table 3.5. Actual pump operations in hours compared with "optimal" and "modified traditional" pump operation protocols at Sidestream Elevated Pool Aeration Station 3 for Water Years 2001, 2003, and 2008.

Operational Scheme/Year	1 Pump	2 Pumps	3 Pumps	Pump hours
2001				
Actual	2788	80	2	2954
Optimal	1184	702	322	3554
Modified Traditional	4097	650	295	6282
2003				
Actual	4065	198	0	4461
Optimal	1801	519	415	4084
Modified Traditional	3396	509	429	5701
2008				
Actual	2466	1564	509	7121
Optimal	1496	291	20	2138
Modified Traditional	4971	239	16	5497

3.3.4 SEPA 4 Operations

SEPA 4 has 4 pumps, but only a maximum of 3 pumps will ever be used at one time with the fourth pump being held in reserve in case of maintenance needs. SEPA 4 is located at RM 311.7 (immediately upstream of Harlem Avenue) on the Calumet-Sag Channel. Considering the results in Table 3.2, the travel times between SEPA 4 and 104th Avenue is approximately 17.4 hours making it a good DO monitoring location for the operation of SEPA 4.

The proposed "optimal" operation protocol for SEPA 4 is as follows. When the DO concentration at 104th Avenue drops below 0.9 mg/L above the at any time DO standard (i.e. less than 4.4 mg/L for August through February and less than 5.9 mg/L for March through July) turn on one pump at SEPA 4, and this pump should remain on until the DO concentration exceeds 0.9 mg/L above the DO standard. If the DO concentration at the DO monitoring location continues to decrease to less than 0.6 mg/L above the at any time DO standard (i.e. less than 4.1 mg/L for August through February and less than 5.6 mg/L for March through July), a second pump should be turned on at SEPA 4, and this pump should remain on until the DO concentration exceeds 0.6 mg/L above the DO standard. Finally, if the DO concentration at the DO monitoring location continues to decrease to less than 0.3 mg/L above the at any time DO standard (i.e. less than 3.8 mg/L for August through February and less than 5.3 mg/L for March through July), a third pump should be turned on at SEPA 4, and this pump should remain on until the DO concentration exceeds 0.3 mg/L above the DO standard.

For the "modified traditional" operation of SEPA 4, one pump is turned on for all actual operational periods in the test years. If the DO concentration at 104th Avenue drops below 0.6 mg/L above the at any time DO standard (i.e. less than 4.1 mg/L for August through February and less than 5.6 mg/L for March through July), a second pump should be turned on at SEPA 4, and this pump should remain on until the DO concentration exceeds 0.6 mg/L above the DO standard. If the DO concentration at 104th Avenue decreases to less than 0.3 mg/L above the at any time DO standard (i.e. less than 3.8 mg/L for August through February and less than 5.3 mg/L for March through July), a third pump should be turned on at SEPA 4, and this pump should remain on until the DO concentration exceeds 0.3 mg/L above the DO standard.

The "optimal" and "modified traditional" operation protocols were applied to SEPA 4 operations for each of WYs 2001, 2003, and 2008. Table 3.6 lists the pump operations determined for each of these schemes as well as the actual pump operations for SEPA 4 for each of the test years. As can be seen in Table 3.6, the "modified traditional" operations resulted in a 45.3% reduction in total pump hours compared to actual operations in WY 2008 because of the large decrease in hours with 2 or 3 pumps on. On the other hand, the "modified traditional" operations resulted in increases of 25.8 and 27.8% in total pump hours compared to the actual operations in WYs 2001 and 2003, respectively. The increase in WYs 2001 and 2003 represents, in part, the increase in the DO standards in this study compared to the DO standard of 3 mg/L at any time considered in the actual SEPA 4 operations in WYs 2001 and 2003, whereas the decrease in WY 2008 occurs despite the increase in DO standards. Also, as can be seen in Table 3.6, the "optimal" operations may result in a 19.5 to 77.8% decrease in total pump hours compared to actual operations. This decrease is even more impressive when the previously discussed increase in DO standards is considered. The 77.8% decrease in WY 2008 may be a little larger than might typically be expected because most of September had 2 or 3 pumps on at SEPA 4, perhaps in an attempt to compensate for SEPA 3 being shut down. Thus, the 19.5 and 23.6% reductions in total pump hours for the "optimal" operations compared to actual operations may be more reflective of typical savings resulting from "optimal" operations. Finally, Table 3.6 indicates the "optimal" operations may result in a 34.1 to 59.4% decrease in total pump hours compared to "modified traditional" operations.

Table 3.6. Actual pump operations in hours compared with "optimal" and "modified traditional" pump operation protocols at Sidestream Elevated Pool Aeration Station 4 for Water Years 2001, 2003, and 2008.

Operational Scheme/Year	**1 Pump**	**2 Pumps**	**3 Pumps**	**Pump hours**
2001				
Actual	4876	2	0	4880
Optimal	1628	629	347	3927
Modified Traditional	4064	554	322	6138
2003				
Actual	3844	398	0	4640
Optimal	1396	594	321	3547
Modified Traditional	3590	526	248	5386
2008				
Actual	1594	1892	1259	9155
Optimal	1420	231	50	2032
Modified Traditional	4538	194	26	5004

3.3.5 Comparison of "Optimal" and "Modified Traditional" Pump Operations

The previous discussion of the actual, "optimal," and "modified traditional" operations of the pumps at SEPA stations 2, 3, and 4 have shown that "optimal" operations offer substantial operational cost savings compared to the actual and "modified traditional" operations at each SEPA station for each of WYs 2001, 2003, and 2008. The most appropriate comparison of operational costs is between "optimal" and "modified traditional" operations because these have both been developed to meet the DO standards adopted by the IPCB in 2016, whereas actual operations were done to meet the lower 3.0 mg/L at any time DO standard.

While the potential operational cost savings are substantial for the "optimal" operations compared to the "modified traditional" operations wherein the SEPA station pumps run nearly continuously from early April to late October/early November, the decrease in attainment of the at any time DO standard accompanying the reduced total pump hours needs to be considered. Table 3.7 lists the percentage attainment of the at any time DO standard for 10 locations on the Little Calumet River (north) and Calumet-Sag Channel for WYs 2001, 2003, and 2008 for the "optimal" and "modified traditional" operations. As can be seen in Table 3.7 for many locations and years the percentage attainment is nearly identical for both the "optimal" and "modified traditional" operations. In only 8 of the 30 comparisons is the difference in attainment greater than 0.1%, and only 3 are greater than 0.2%. Figure 3.4 compares the simulated DO concentrations for the "optimal" and "modified traditional" operations for 6 selected locations for WY 2003 as an example. From Figure 3.4 it can be seen that for the "modified traditional" operations a large portion of the SEPA operations occur during periods with high DO concentrations (i.e. above the at any time DO standard), hence demonstrating the inefficiency of operating the SEPA stations continuously from early April to late October/early November. From Figure 3.4, it is clear to see why the "optimal" operations can achieve essentially the same attainment of the at any time DO standard for far smaller total pump hours.

Table 3.7. Percentage of time meeting or exceeding (i.e. attaining) the at any time dissolved oxygen standard on the Little Calumet River (north) and Calumet-Sag Channel for Water Years 2001, 2003, and 2008 for the cases of "optimal" and "modified traditional" operations of the Sidestream Elevated Pool Aeration stations.

Location	**2001**		**2003**		**2008**	
	Traditional	**Optimal**	**Traditional**	**Optimal**	**Traditional**	**Optimal**
Conrail Railroad	98.26	98.25	96.59	96.59	99.35	98.85
Central & Wisconsin Railroad	99.11	99.11	97.51	97.51	99.50	99.41
Halsted Street	98.80	98.80	97.21	97.17	99.80	99.78
Division Street	97.51	97.52	97.93	97.88	99.98	99.97
Kedzie Avenue	99.68	99.70	99.44	99.46	100.00	100.00
Cicero Avenue	98.50	98.50	98.28	98.13	99.97	99.98
Harlem Avenue	99.61	99.61	99.29	98.84	99.95	99.99
Southwest Highway	99.38	99.39	99.10	98.69	99.95	99.99
104th Avenue	98.09	98.11	98.48	98.24	99.94	99.83
Route 83	96.26	96.10	97.33	97.23	99.86	99.89

Considering efficiency and effectiveness the "optimal" operation protocol appears to be superior to the "modified traditional" operation protocol. However, the operations of the SEPA stations have other benefits to the MWRDGC and the Chicago area in addition to improvement in DO concentrations. The SEPA stations also provide aesthetic and social benefits to the southern suburbs in Cook County. For example, the MWRDGC web site contains the following statement regarding these benefits (http://www.mwrd.org/irj/portal/anonymous/sepa):

> *"While not all SEPA stations are accessible to the public, SEPA Station 4 is a popular destination for wedding and special event portraits. The District welcomes the public to use and enjoy this beautiful setting as a portrait backdrop and there is no fee to do so,*

but we require that you notify us prior to arrival. Please call the Office of Public Affairs at 312-751-6633 at least 3 days in advance of your planned visit. Also, please be aware that there is no alcohol allowed and no actual ceremonies may take place on the park grounds. The SEPA Station and surrounding grounds are public spaces and cannot be reserved. There will likely be other people, possibly other wedding parties, present on the day of your visit."

Thus, when developing the strategy for the operation of the SEPA stations, the MWRDGC considered the cost of operations, as well as aesthetic, social, and other benefits, such that the final strategy did not sacrifice the SEPA stations' performance relative to the DO standards.

SEPA 2 is the smallest SEPA station and would seem to have minimal aesthetic and social benefits, however, the MWRDGC decided to continue to operate one pump continuously at SEPA 2 from April 1 to October 31 as per the DO variance petition. Two pumps at SEPA 2 would be operated as needed as per the "modified traditional" protocol previously described.

As noted previously, SEPA 4 is highly accessible to the public in a park and often is used a backdrop for wedding photos, thus, its aesthetic and social value is high. Since nearly all the periods that result in low DO concentrations occur in May through September, the MWRDGC decided that SEPA 4 should be operated with one pump continuously from May 1 to September 30, and on an as needed basis (per the DO measurements at 104th Avenue) during the rest of the year. This approach provides substantial cost savings relative to traditional operations without negatively affecting the aesthetic and social benefits of SEPA 4. Two and three pumps at SEPA

4 would be operated as needed as per the "modified traditional" protocol previously described. The same operational protocol was adopted for SEPA 3 and SEPA 5.

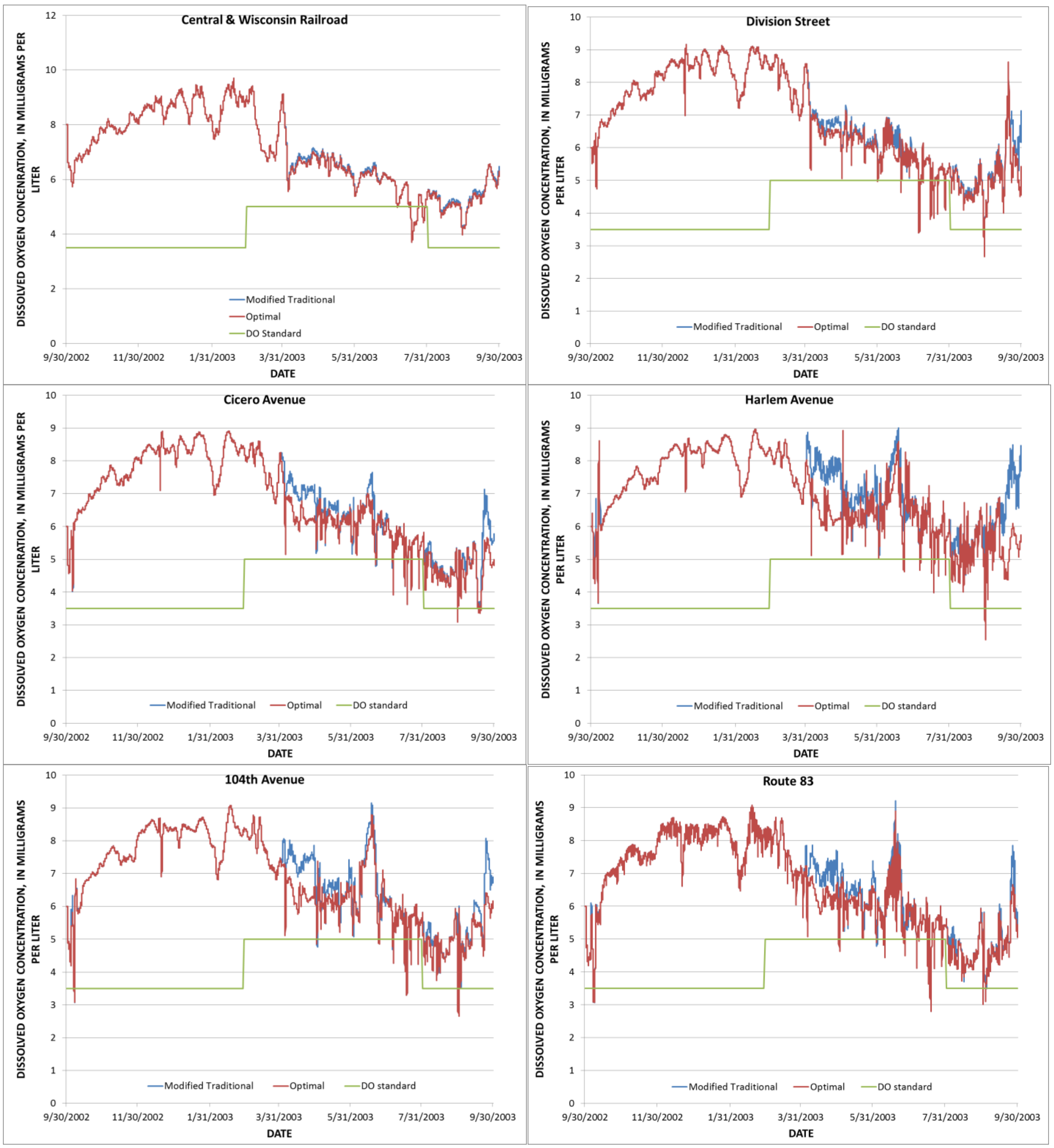

Figure 3.4. Simulated dissolved oxygen concentrations at various locations along the Little Calumet River (north) and Calumet-Sag Channel for Water Year 2003 for "modified traditional" and "optimal" operations of the Sidestream Elevated Pool Aeration stations.

Chapter 4 “Year Specific” Optimal Guidance

4.1 Adjusting CSO and WRP Flows to Account for Thornton Reservoir and Stage 1 of the McCook Reservoir Operations

As noted earlier, the operational guidance presented in Chapters 2 and 3 was developed considering the estimated actual CSO flows to the CAWS for WYs 2001, 2003, and 2008, which was a period for which the annual average discretionary diversion from Lake Michigan was limited to 270 cfs. On September 22, 2016, the IDNR issued its Final Administrative Decision on a Petition for Modification of Allocation Permit by Metropolitan Water Reclamation District of Greater Chicago (LMO-14-5). In this decision the allowable discretionary diversion was reduced from 270 cfs to 220 cfs beginning in WY 2018. Also in WY 2015, the Thornton Reservoir was completed and brought into operation changing the amount and frequency of CSOs to the Little Calumet River and Calumet-Sag Channel. During WY 2018, Stage 1 of the McCook Reservoir was completed and brought into operation changing the amount and frequency of CSOs to the NSC, NBCR, Chicago River main stem, SBR, and CSSC. Therefore, the final operational guidance needs to consider inflows to the CAWS that reflect the operations of these reservoirs and the reduced maximum allowable annual discretionary diversion. The effects of the reservoirs on the flows to and in the CAWS for WYs 2001, 2003, and 2008 were determined for the Baseline conditions of the GLMRIS study (Melching and Liang, 2013).

For the actual inflow conditions for WYs 2001, 2003, and 2008, estimates of the gravity CSO flows to the modeled portion of the CAWS were obtained from the series of models developed by the USACE, Chicago District, to simulate the flows in the TARP system. The Hydrological

Simulation Program—Fortran (HSPF) is used to simulate surface and subsurface runoff from the drainage basin on the basis of precipitation measured by the network of 25 precipitation gages maintained by the Illinois State Water Survey as part of the accounting of flows diverted from the Lake Michigan watershed by the State of Illinois (see, for example, Westcott, 2002). The output flows from HSPF are input to the Special Contributing Area Loading Program (SCALP) which simulates the flows in the major interceptor sewers in the Chicago area. The output from the SCALP program is then input to the Tunnel Network (TNET) model, which determines which potential CSOs can enter the TARP system via the drop shafts and which will go directly to the CAWS as CSOs. A detailed discussion of the USACE models is given in Espey et al. (2004). The simulated CSO flows obtained from the USACE models then were aggregated to determine the total inflow to the CAWS from each of the 43 representative CSO locations (see Melching et al., 2010; Melching and Liang, 2013).

For the GLMRIS Baseline conditions the USACE models were run again for each of WYs 2001, 2003, and 2008 for the case of the Thornton Reservoir and Stage 1 of the McCook Reservoir in operation. The simulated CSO flows obtained from the USACE models for the case of the reservoirs in operation then were aggregated to determine the total inflow to the CAWS from each of the 43 representative CSO locations. These CSO inflows then were input to the DUFLOW model at each of the representative CSO locations. The difference in CSO inflows with and without reservoirs then was summed to determine a portion of the inflow to the Thornton and Stage 1 of the McCook reservoirs. This stored water is assumed to be pumped out from the reservoirs as capacity is available at the Stickney WRP for McCook or Calumet WRP for Thornton. Typically the pump out of the reservoir is started after the tunnels have been pumped out. The pump out of the tunnels is indicated in the flow record from the WRPs by the periods when the WRP is discharging at or above its capacity (430 million gallons per day [mgd] for the Calumet WRP and 1,200 mgd for the Stickney WRP). In actual operations flows above the capacity of the plants occur when the tunnels are being drained, but in the GLMRIS study (and this study) the rate at which the reservoirs are drained is the difference between the actual inflows to the WRP and its capacity. Also, it is assumed that the increased effluent flow has the same quality (i.e. constituent concentrations) as for the actual effluent on that day. That is, the WRP performance is assumed to be unaffected by the increased flow. Similarly, the concentrations of pollutants in the CSOs are considered to be the same as for the actual conditions in WYs 2001, 2003, and 2008 (see Melching et al., 2010; Melching and Liang, 2013). Thus, it is assumed that the reduction in "first flush effects" and subsequent reduction in the concentration of pollutants in the CSOs accomplished by the TARP tunnels adequately describes the capture of pollutants by the reservoirs.

Several CSOs are present on the North Branch Chicago River upstream of Albany Avenue and the Little Calumet River upstream of the USGS gage at South Holland whose flows will be affected by the operation of Stage 1 of the McCook Reservoir and Thornton Reservoir, respectively. For these locations the difference in the CSO flows from the USACE model runs with and without the reservoirs was determined and summed for the CSO locations upstream of each USGS streamflow gage—Albany Avenue and South Holland. If the difference was less than the measured flow, it was subtracted from the 1 hr flows measured by the USGS and the difference was considered an inflow to the appropriate reservoir. If the difference was greater than the measured flow at the Albany Avenue or South Holland gages, as appropriate, the inflow was set to zero, and the streamflow value was considered an inflow to the appropriate reservoir.

Finally, the flows from the CSO pumping stations are affected by the operation of the TARP reservoirs. For the North Branch, Racine Avenue, and 125th Street pumping stations the percentage decrease in CSO flows for the areas tributary to these pumping stations were determined from the USACE models for the case of the reservoirs in operation relative to the case without reservoirs. The percentage reductions then were applied to the CSO flows for these pumping stations estimated from pump capacity and operations. The flow reductions at these pumping stations were considered inflows to the appropriate reservoir.

The DUFLOW model of the CAWS is hydraulically driven by upstream boundary conditions (at the WPS, CRCW, and O'Brien L&D) of flow versus time (which will be specified as part of the determination of the discretionary diversion guidance) and flow on the Little Calumet River at South Holland; the inflows from the CSOs, tributaries, and WRPs; and the downstream boundary condition of water level versus time at the Lockport Controlling Works (LCW). With the change in the storm inflows resulting from reservoir operations the downstream water level at the LCW also will change compared to the measured values. Subsection 5.2.2 in Melching and Liang (2013) details how these changes were determined for the GLMRIS Baseline conditions. These changes in the downstream boundary condition also were applied in this study.

4.1.1 Water Year 2001

Table 4.1 lists the percentage of CSO flows captured by Stage 1 of the McCook Reservoir and Thornton Reservoir. On average, well above 90% of the total without reservoir CSO flows for WY 2001 are captured and stored by the reservoirs, especially for the Calumet TARP system which captures more the 99.8% of the without reservoir CSO flows.

Table 4.1. Percentage of combined sewer overflows (CSOs) captured by Stage 1 of the McCook Reservoir for Water Years 2001, 2003, and 2008.

Water Year	Stage 1 of the McCook Reservoir			Thornton Reservoir	
	Gravity CSOs	Racine Avenue	North Branch	Gravity CSOs	125th Street
2001	90.0	98.3	99.5	99.8	100.0
2003	83.6	95.7	84.4	95.7	96.8
2008	60.2	85.4	77.1	49.9	76.5

Figure 4.1 shows the sum of the gravity CSOs to the Chicago River system for the current (no reservoir) and the GLMRIS Baseline (with reservoir) conditions. With Stage 1 of the McCook Reservoir in operation, only August 2nd, experiences substantial CSO flows and very small CSOs occur on July 25th, August 30th, and September 18th. Figure 4.1 and Table 4.1 clearly show the effectiveness of Stage 1 of the McCook Reservoir. Figure 4.2 shows the simulated storage in Stage 1 of the McCook Reservoir for the GLMRIS Baseline conditions and the flows from the Stickney WRP under current (actual) and Baseline conditions (reflecting the pumping out of the reservoir).

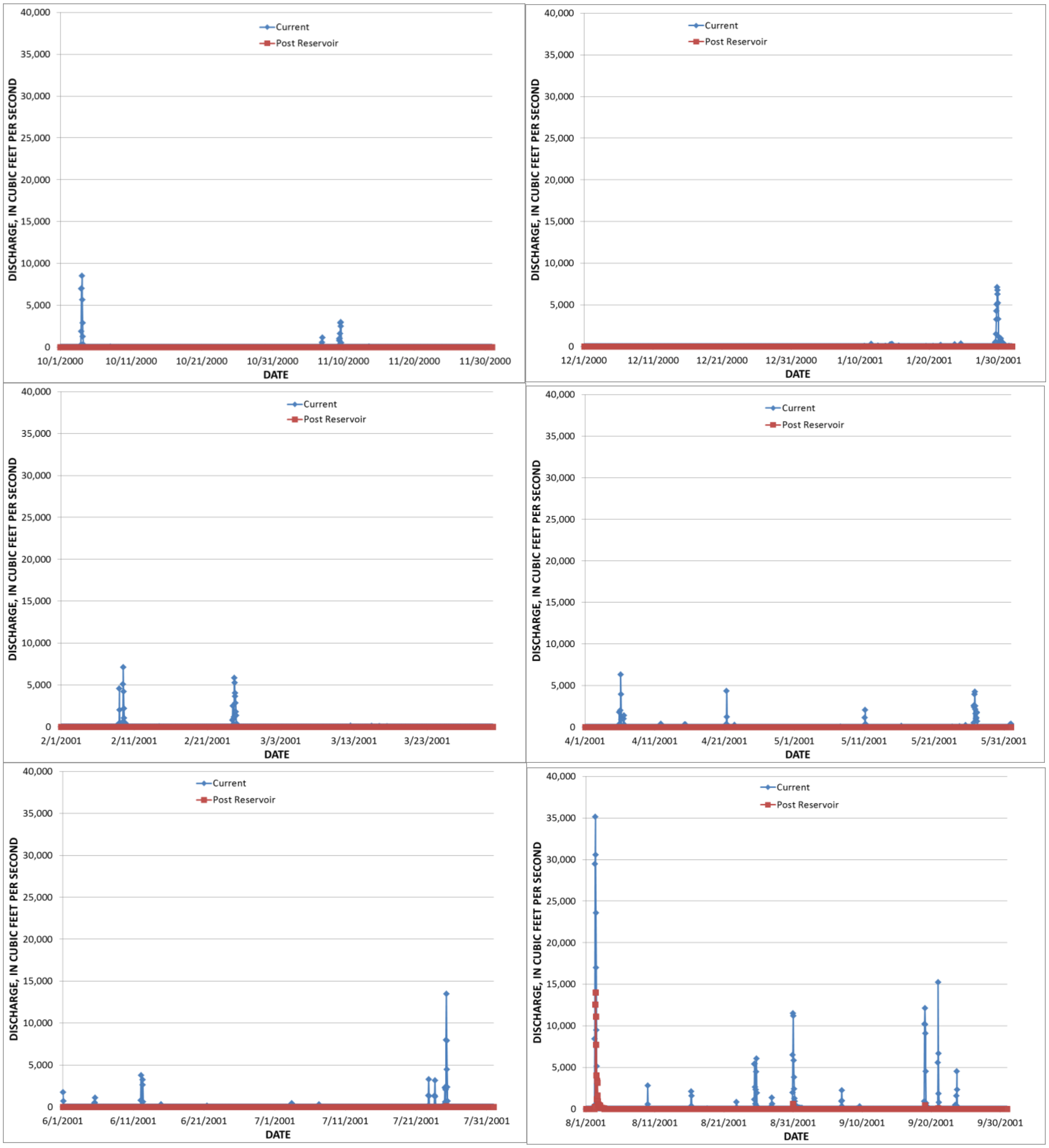

Figure 4.1. Sum of combined sewer overflows to the Chicago River system under current (no reservoir) conditions and GLMRIS Baseline (Stage 1 of the McCook Reservoir operational, i.e. post reservoir) conditions for Water Year 2001.

Figure 4.3 shows the sum of the gravity CSOs to the Calumet River system for the current (no reservoir) and the GLMRIS Baseline (with reservoir) conditions. With the Thornton Reservoir in operation, only very small CSOs occur on August 2nd and 25th. Figure 4.3 and Table 4.1 clearly show the effectiveness of the Thornton Reservoir. Figure 4.4 shows the simulated storage in the Thornton Reservoir for the GLMRIS Baseline conditions and the flows from the Calumet WRP under current (actual) and Baseline conditions (reflecting the pumping out of the reservoir).

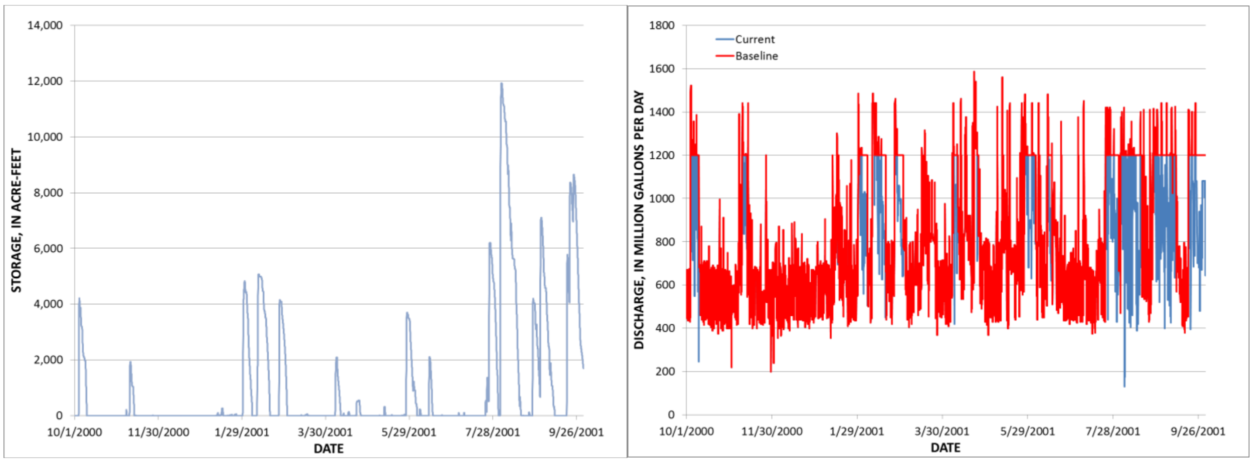

Figure 4.2. Storage in Stage 1 of the McCook Reservoir for GLMRIS Baseline conditions (left) and effluent from the Stickney Water Reclamation Plant for current (no reservoir) and Baseline conditions for Water Year 2001.

4.1.2 Water Year 2003

Table 4.1 lists the percentage of CSO flows captured by Stage 1 of the McCook Reservoir and Thornton Reservoir. On average, well above 83% of the total without reservoir CSO flows for WY 2003 are captured and stored by the reservoirs, especially for the Calumet TARP system which captures more the 95% of the without reservoir CSO flows. It may seem odd that the reservoirs capture higher percentages of CSO flows for the representative "normal" year (WY 2001) than for the representative "dry" year (WY 2003). Whereas WY 2003 is substantially drier than WY 2001, early May 2003 experienced a series of storms that filled the Mainstream tunnels and Stage 1 of the McCook Reservoir and late July experienced a series of several storms that filled the Calumet tunnels and Thornton Reservoir such that, in each case, only small portions of the combined sewer flows from the later storms can be captured as can be seen in Figures 4.5-4.8.

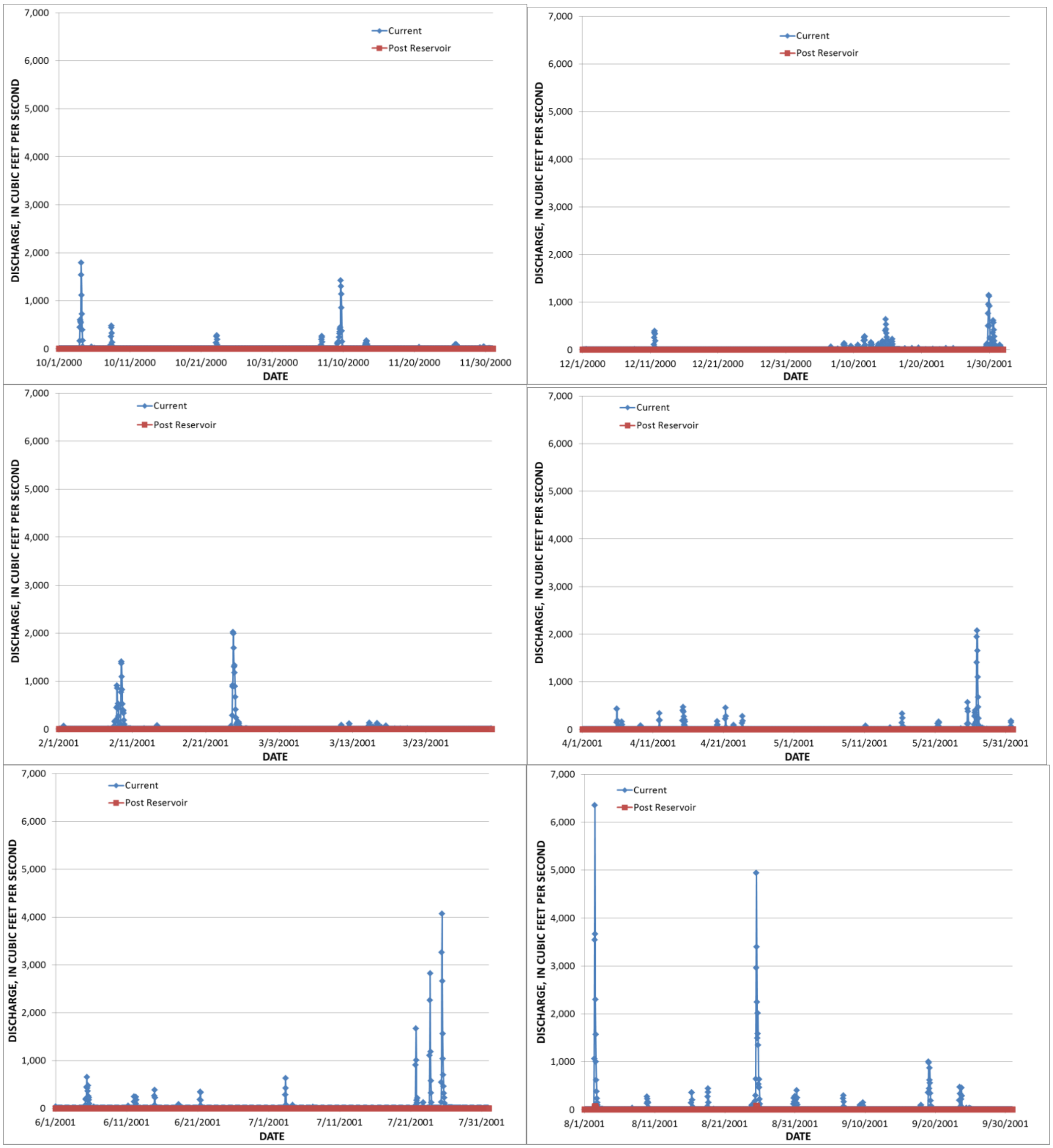

Figure 4.3. Sum of combined sewer overflows to the Calumet River system under current (no reservoir) conditions and GLMRIS Baseline (Thornton Reservoir operational, i.e. post reservoir) conditions for Water Year 2001.

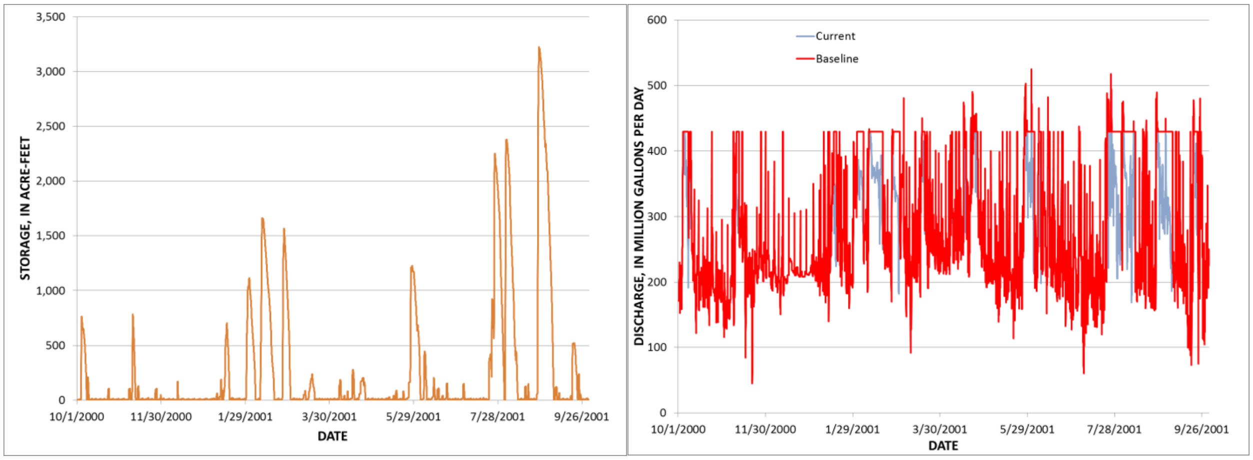

Figure 4.4. Storage in the Thornton Reservoir for Baseline conditions (left) and effluent from the Calumet Water Reclamation Plant for current (no reservoir) and GLMRIS Baseline conditions for Water Year 2001.

Figure 4.5 shows the sum of the gravity CSOs to the Chicago River system for the current (no reservoir) and the GLMRIS Baseline (with reservoir) conditions. With Stage 1 of the McCook Reservoir in operation, May 5th, 9th, and 11th experience substantial CSO flows, and very small CSOs occur on May 1st and 10th. Outside of May no CSOs occur with Stage 1 of the McCook Reservoir in operation. Figure 4.5 and Table 4.1 clearly show the effectiveness of the McCook Reservoir Stage 1. Figure 4.6 shows the simulated storage in the McCook Reservoir Stage 1 for GLMRIS Baseline conditions and the flows from the Stickney WRP under current (actual) and Baseline conditions (reflecting the pumping out of the reservoir).

Figure 4.7 shows the sum of the gravity CSOs to the Calumet River system for the current (no reservoir) and the GLMRIS Baseline (with reservoir) conditions. With the Thornton Reservoir in operation, substantial CSOs occur on July 17th and 27th and only very small CSOs occur on August 11th. Figure 4.7 and Table 4.1 clearly show the effectiveness of the Thornton Reservoir. Figure 4.8 shows the simulated storage in the Thornton Reservoir for GLMRIS Baseline conditions and the flows from the Calumet WRP under current (actual) and Baseline conditions (reflecting the pumping out of the reservoir).

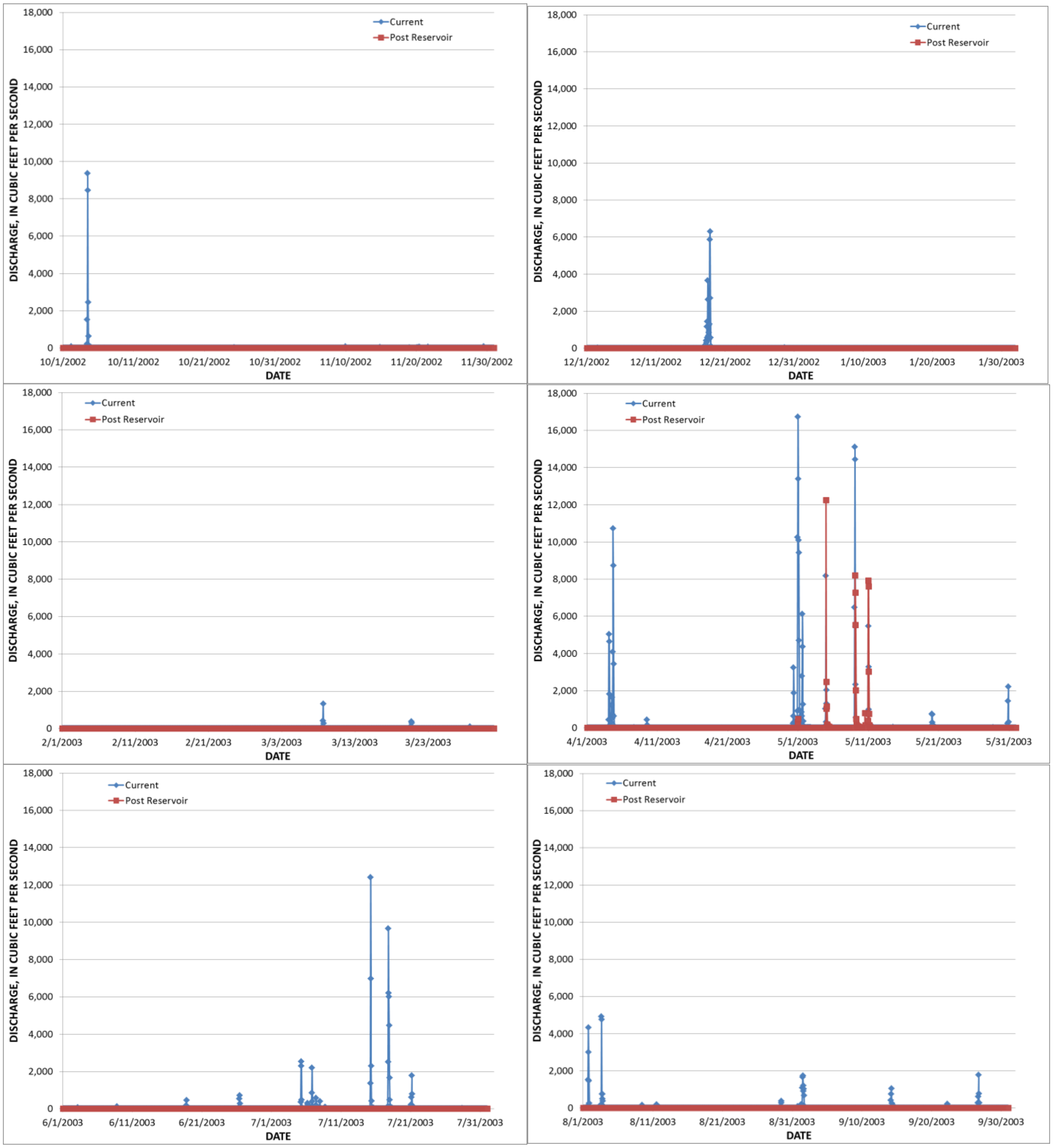

Figure 4.5. Sum of combined sewer overflows to the Chicago River system under current (no reservoir) conditions and GLMRIS Baseline (Stage 1 of the McCook Reservoir operational, i.e. post reservoir) conditions for Water Year 2003.

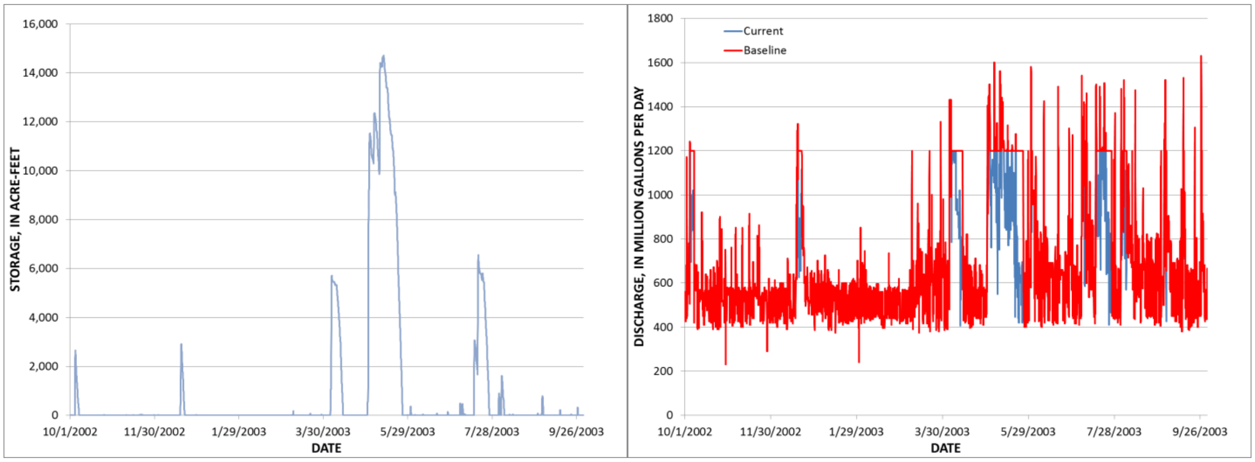

Figure 4.6. Storage in Stage 1 of the McCook Reservoir for GLMRIS Baseline conditions (left) and effluent from the Stickney Water Reclamation Plant for current (no reservoir) and Baseline conditions for Water Year 2003.

4.1.3 Water Year 2008

Table 4.1 lists the percentage of CSO flows captured by Stage 1 of the McCook Reservoir and Thornton Reservoir. On average, above 50% of the total without reservoir CSO flows for WY 2008 are captured and stored by the reservoirs. The percentage captured for WY 2008 is far smaller than for WYs 2001 and 2003 because of the unique sequence of storms in early to mid-September 2008. The storms of September 4th and 8th fill the reservoirs and tunnels, such that very little of the combined sewer flows from the storms of September 13th to 16th are captured in the reservoirs and the CSOs discharge to the CAWS almost the same as they did for the no reservoir case for this largest storm in the three year study period as can be seen in Figures 4.9-4.12.

Figure 4.9 shows the sum of the gravity CSOs to the Chicago River system for the current (no reservoir) and GLMRIS Baseline (with reservoir) conditions. With Stage 1 of the McCook Reservoir in operation, February 17th, August 5th, and September 4th and 8th experience substantial CSO flows, and September 13th to 16th experience massive CSO flows. Consideration of the conditions in WY 2008 clearly shows the need for Stage 2 of the McCook Reservoir.

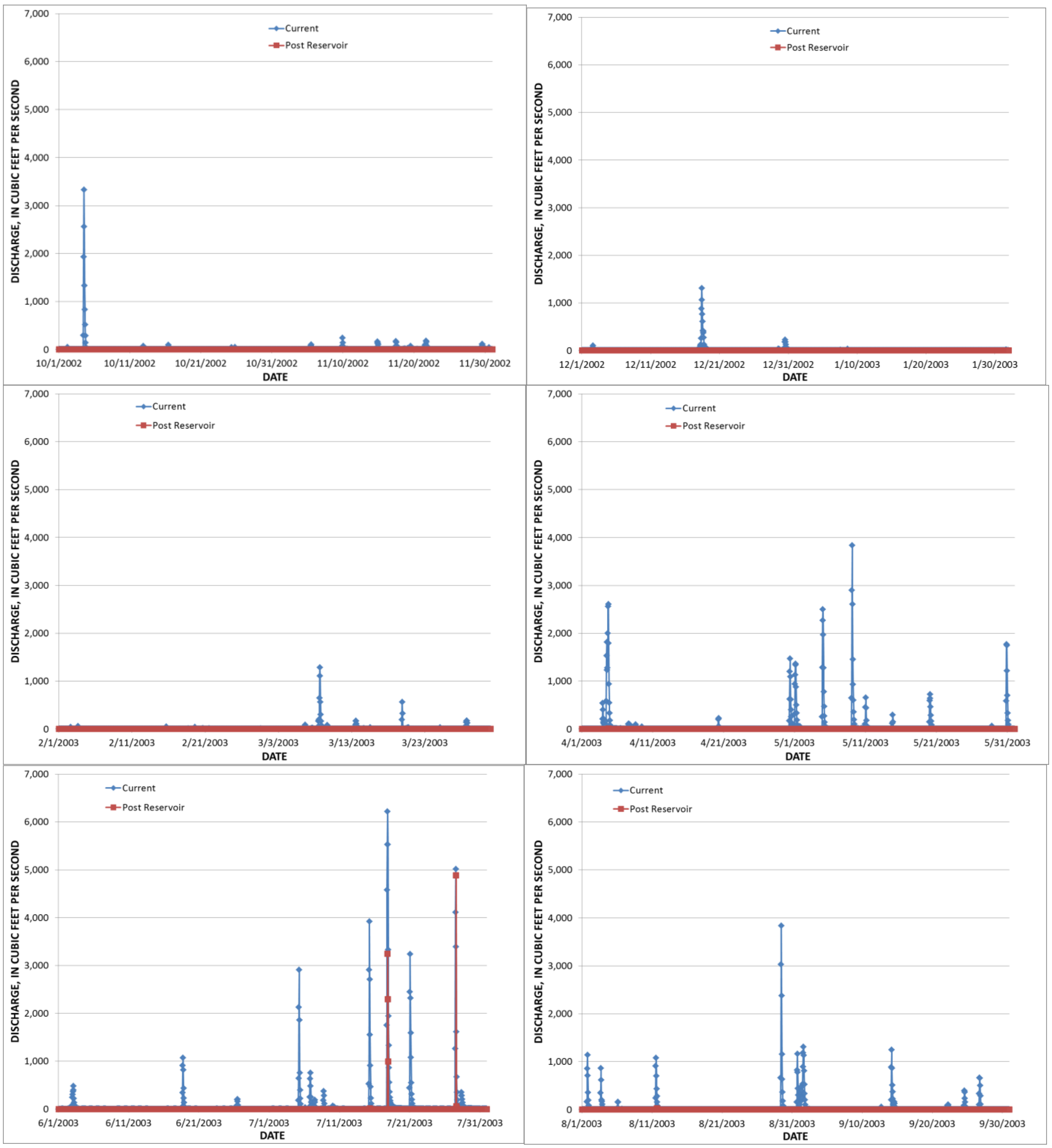

Figure 4.7. Sum of combined sewer overflows to the Calumet River system under current (no reservoir) conditions and GLMRIS Baseline (Thornton Reservoir operational, i.e. post reservoir) conditions for Water Year 2003.

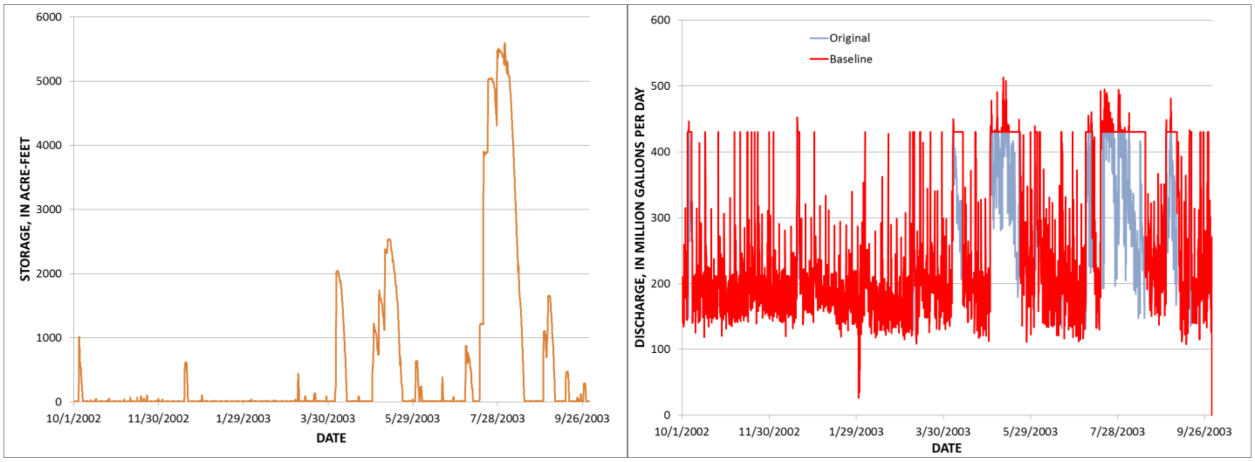

Figure 4.8. Storage in the Thornton Reservoir for GLMRIS Baseline conditions (left) and effluent from the Calumet Water Reclamation Plant for original (no reservoir) and Baseline conditions for Water Year 2003.

Figure 4.10 shows the simulated storage in Stage 1 of the McCook Reservoir for GLMRIS Baseline conditions and the flows from the Stickney WRP under current (actual) and Baseline conditions (reflecting the pumping out of the reservoir).

Figure 4.11 shows the sum of the gravity CSOs to the Calumet River system for the current (no reservoir) and the GLMRIS Baseline (with reservoir) conditions. With the Thornton Reservoir in operation, very small CSOs occur on January 7th, February 17th, May 11th, August 4th, and September 4th, and then September 13th to 16th experience massive CSO flows. Figure 4.11 and Table 4.1 clearly show the limitations in effectiveness of the Thornton Reservoir. Figure 4.12 shows the simulated storage in the Thornton Reservoir for GLMRIS Baseline conditions and the flows from the Calumet WRP under current (actual) and Baseline conditions (reflecting the pumping out of the reservoir).

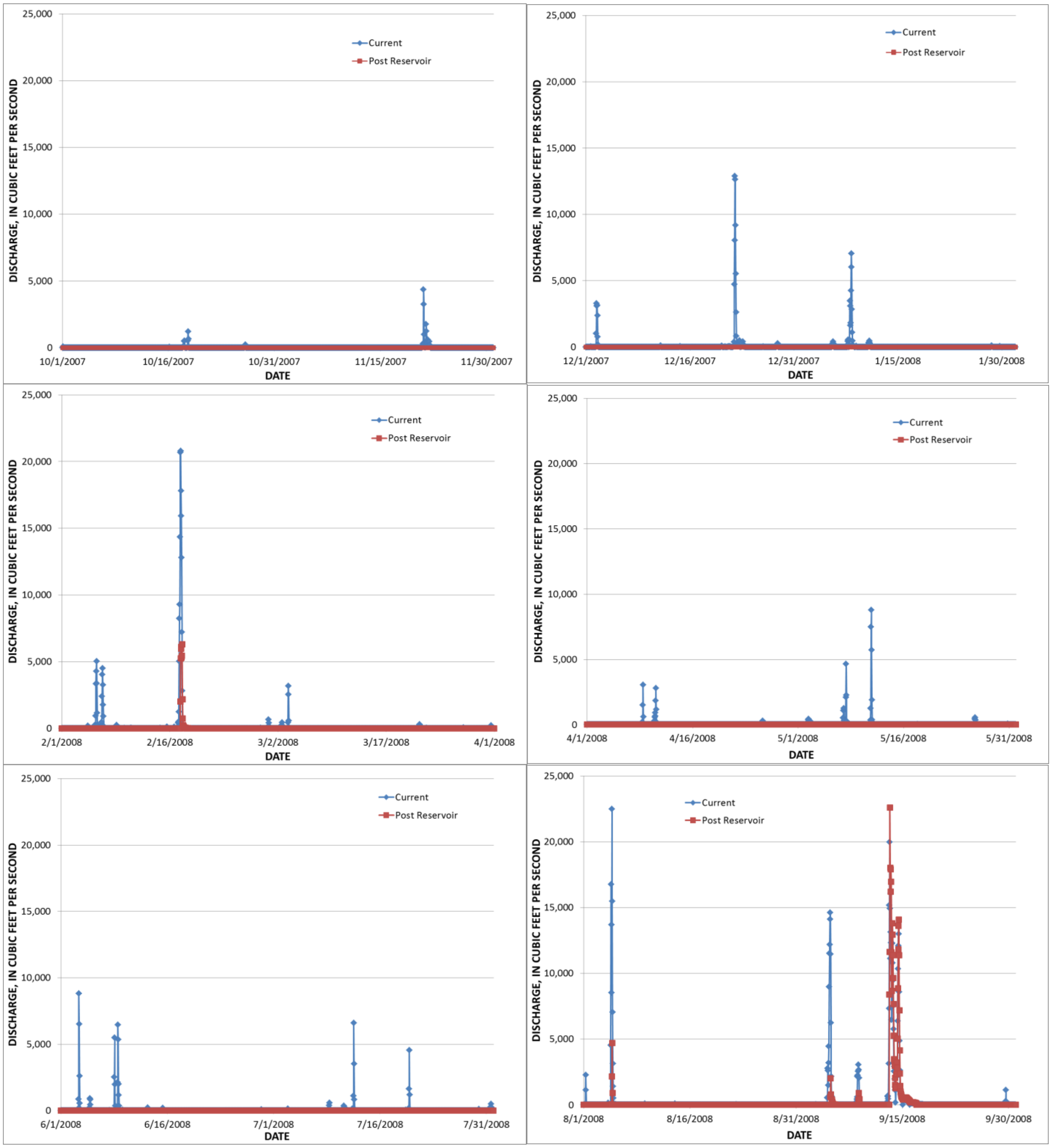

Figure 4.9. Sum of combined sewer overflows to the Chicago River system under current (no reservoir) conditions and GLMRIS Baseline (Stage 1 of the McCook Reservoir operational, i.e. post reservoir) conditions for Water Year 2008.

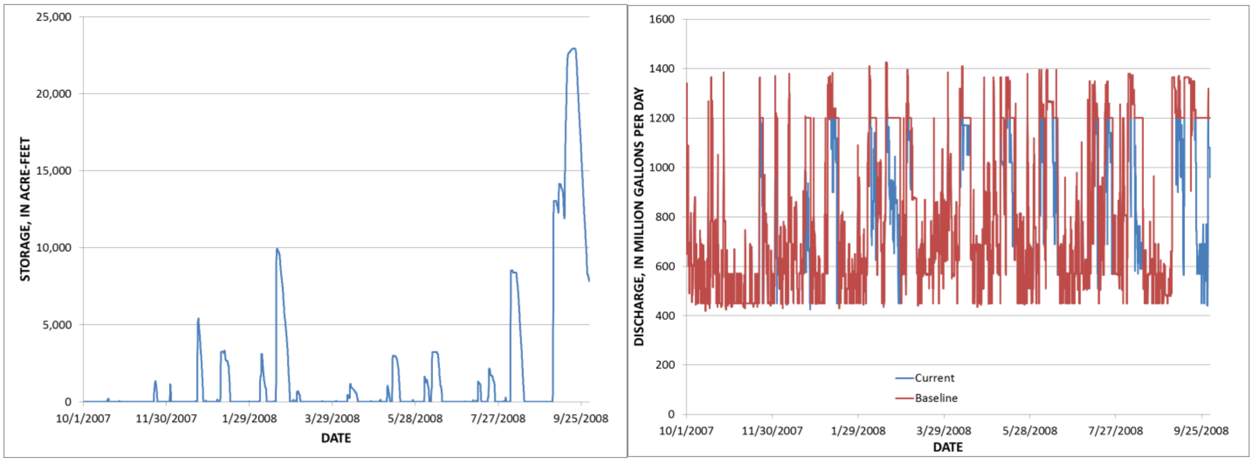

Figure 4.10. Storage in Stage 1 of the McCook Reservoir for GLMRIS Baseline conditions (left) and effluent from the Stickney Water Reclamation Plant for current (no reservoir) and Baseline conditions for Water Year 2008.

4.2 Operational Guidance for Discretionary Diversion and Aeration to the North Shore Channel and North Branch Chicago River

A review of measured DO concentrations at CRCW was done for days when discretionary diversion or navigation make-up water was taken, i.e. conditions at CRCW were dominated by Lake Michigan water. Typically, when the conditions at the CRCW DO monitor were dominated by Lake Michigan water, the DO concentrations ranged from about 70% of saturation to 120% of saturation. Overall 90.6% of saturation was the average condition on days with discretionary diversion. Thus, for the periods when discretionary diversion is withdrawn at the CRCW for WYs 2001 and 2003 the DO concentration assigned to these flows is the maximum of the measured DO concentration and 90.6% of saturation.

For WY 2008 no measured DO concentrations were available, thus, Melching and Liang (2013) estimated the hourly DO concentrations at the CRCW on the basis of linear regression equations relating the hourly DO concentration at Clark Street on the Chicago River main stem with that at

CRCW. Two relations were developed by Melching and Liang (2013), one for periods when discretionary diversion was taken at the CRCW and the other for periods without discretionary diversion at the CRCW. In the development of the "optimal" guidance for withdrawal of discretionary diversion at CRCW, for periods when discretionary diversion is withdrawn at the CRCW the DO concentration assigned to these flows is the maximum of the value estimated from the measured DO concentration at Clark Street and 90.6% of saturation. For periods without discretionary diversion the average percentage of saturation during periods without discretionary diversion (79.6%) is applied to the saturation DO concentrations.

4.2.1 Discretionary Diversion Guidance and Limitations

Compared to the results presented in Chapter 2 the following changes in the procedures for withdrawal of discretionary diversion at the WPS were made for the final operational guidance:

A) The MWRDGC has decided to continuously withdraw 100 cfs of discretionary diversion from May 15 to September 30 to avoid stagnant flow conditions in the NSC during summer and late spring. This will result in more discretionary diversion being taken at the WPS than for the procedures described in Chapter 2, but it will not result in an inefficient use of discretionary diversion. Low DO concentrations occur at nearly all times at Loomis Street on the SBCR in May through September. Simulation results have found that withdrawal of discretionary diversion at the WPS has nearly the same positive effect on DO at Loomis Street as withdrawal of discretionary diversion at the CRCW because the O'Brien WRP is the primary source of pollutants to the SBCR and counteracting these pollutants near their source has benefits all the way to the SBCR.

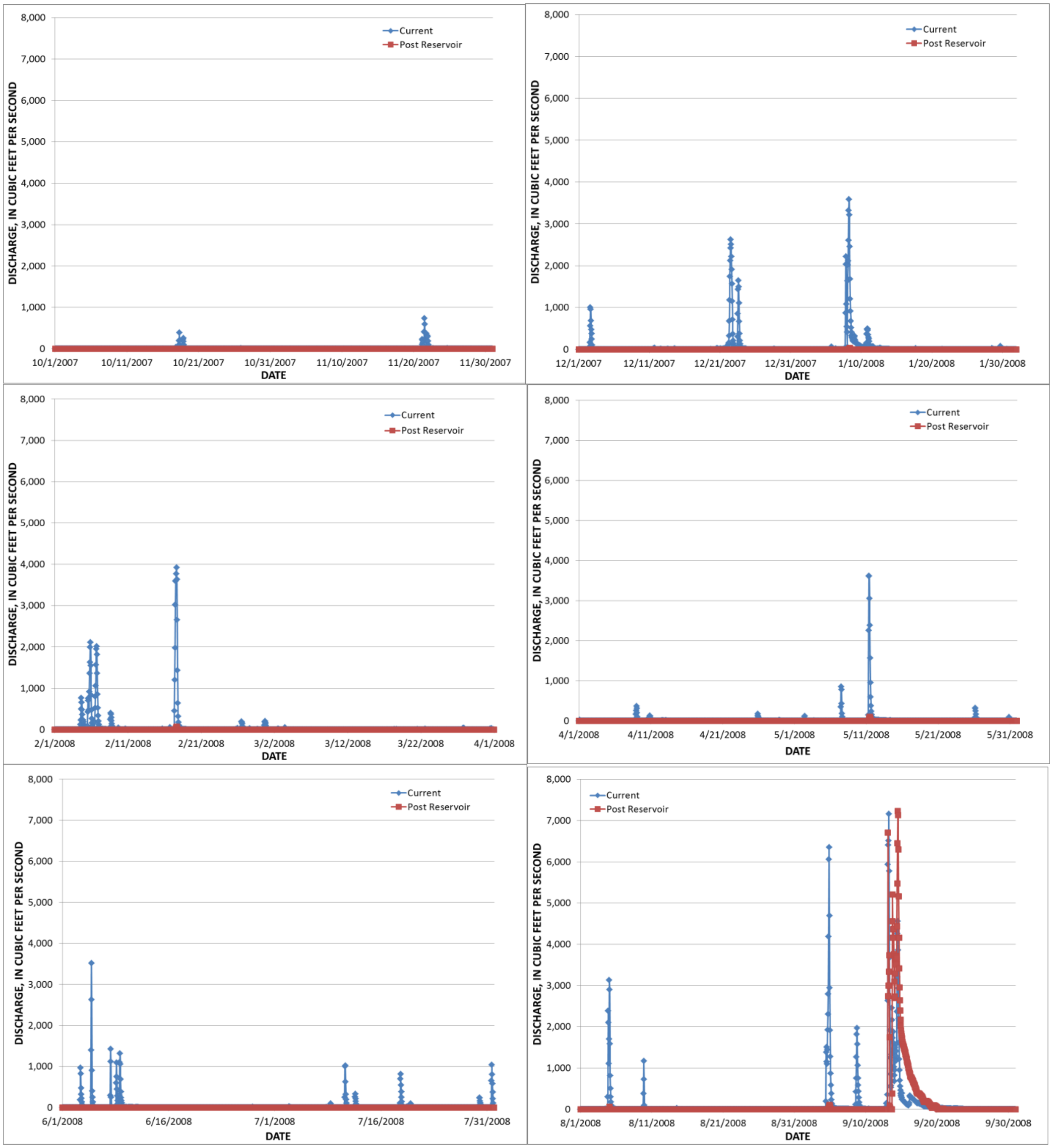

Figure 4.11. Sum of combined sewer overflows to the Calumet River system under current (no reservoir) conditions and GLMRIS Baseline (Thornton Reservoir operational, i.e. post reservoir) conditions for Water Year 2008.

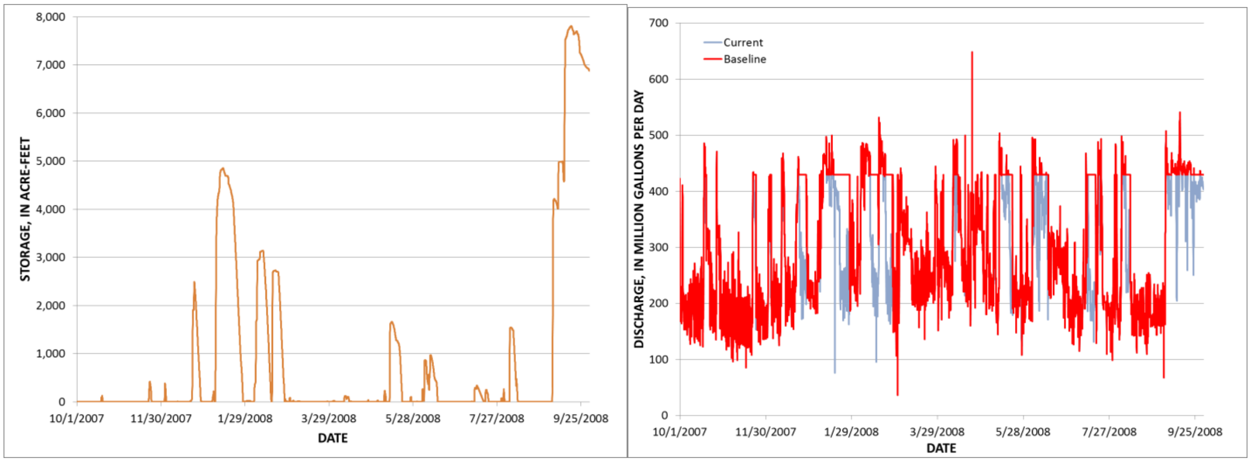

Figure 4.12. Storage in the Thornton Reservoir for GLMRIS Baseline conditions (left) and effluent from the Calumet Water Reclamation Plant for current (no reservoir) and Baseline conditions for Water Year 2008.

B) Outside of May 15 to September 30, periods with DO concentrations less than the at any time DO standard plus 0.3 mg/L (i.e. 3.8 mg/L for October through February and 5.3 mg/L for March 1 through May 14) were identified at Church Street and Main Street on the NSC. During these periods 50 cfs of discretionary diversion are withdrawn.

C) Under actual conditions on August 2, 2001 and August 31, 2001 flow reversals to Lake Michigan at the WPS occurred as a result of heavy storm (CSO flows) to the CAWS. With Stage 1 of the McCook Reservoir operational these heavy storm flows would be captured by the reservoir. Thus, no flow reversals would occur and, in fact, it would be feasible to take discretionary diversion during these periods for which it was impossible to take discretionary diversion during actual conditions. Thus, 100 cfs of discretionary diversion also was applied to these periods.

D) Under actual conditions in WY 2008, a flow reversal to Lake Michigan occurred at the WPS from 6:18 on September 13 to 7:30 on September 16. Further, no discretionary diversion could be taken until 15:10 on September 20 when the interior water levels dropped to acceptable levels at the WPS. Because the CSO flows to the CAWS were minimally affected by Stage 1 of the McCook Reservoir for the storm of September 13 to 16, 2008 (see Subsection 4.1.3), no discretionary diversion was allowed at the WPS between 0:00 of September 13 to 15:10 on September 20 in the simulations to determine of the "optimal" discretionary diversion for WY 2008.

4.2.2 Instream Aeration Stations

As discussed in Subsection 2.3.5, the Devon Avenue and Webster Avenue IASs are operated with a maximum of 2 blowers. The specific operational procedures are as follows where the DO monitor for operation of the Devon Avenue IAS is Fullerton Avenue and the DO monitor for operation of the Webster Avenue IAS is Ohio Street (Kinzie Street serves as surrogate for the existing DO monitor at Ohio Street in the simulations):

1. All blowers are off whenever DO concentrations at the monitoring location are at least 1.0 mg/L above the at any time DO standard (i.e. 4.5 mg/L for August to February and 6.0 mg/L for March through July).
2. Start one blower if the DO concentration drops below 1.0 mg/L above the at any time DO standard (i.e. 4.5 mg/L for August to February and 6.0 mg/L for March through July) and leave it on until the DO concentration is greater than 1.0 mg/L above the DO standard.
3. Start a second blower if the DO concentration drops below 0.7 mg/L above the at any time DO standard (i.e. 4.2 mg/L for August to February and 5.7 mg/L for March through July) and leave it on until the DO concentration is greater than 0.7 mg/L above the DO standard.

4.2.3 Results

Table 4.2 lists the level of attainment of the at any time DO standard at various DO monitoring locations on the NSC and NBCR for WYs 2001, 2003, and 2008 applying the procedures described in Subsections 4.2.1 and 4.2.2. Table 4.3 lists the level of attainment of the 7-day mean of the daily minimum DO standard at various DO monitoring locations on the NSC and NBCR for WYs 2001, 2003, and 2008 applying the procedures described in Subsections 4.2.1 and 4.2.2. When the IDNR set the allowable annual discretionary diversion limit of 220 cfs a goal was to attain the DO standards at least 95% of the time at all locations in the CAWS. From Tables 4.2 and 4.3 it can be seen that this goal is achieved at all locations and years except for the 7-day mean of the minimum daily DO standard at Simpson Street for WY 2008. The reason the 95% attainment goal could not be met for the 7-day mean of daily minimum DO standard at Simpson Street is that nearly half of the non-attainment occurs between September 18 and 25 and little could be done about this because discretionary diversion could only be taken beginning at 15:10 on September 20. That is, the 7-day mean is affected by several days with no discretionary diversion during this period, and, thus, there is no way to raise the mean above the DO standard.

Table 4.2. Percentage of time the at any time dissolved oxygen standard is equaled or exceeded (i.e. attained) on the North Shore Channel (NSC) and North Branch Chicago River (NBCR) for WYs 2001, 2003, and 2008 applying the proposed guidelines for withdrawal of discretionary diversion at the Wilmette Pumping Station and operation of the Devon Avenue and Webster Avenue instream aeration stations.

Location	Waterway	2001	2003	2008
Simpson Street	NSC	99.79	99.10	99.48
Main Street	NSC	99.35	97.22	99.06
Foster Avenue	NSC	99.62	99.97	99.58
Addison Street	NBCR	99.09	99.78	100.00
Fullerton Avenue	NBCR	98.53	99.45	99.99
Division Street	NBCR	99.63	100.00	100.00
Kinzie Street	NBCR	99.58	100.00	100.00

Table 4.3. Percentage of days the 7-day mean of the daily minimum dissolved oxygen standard is equaled or exceeded (i.e. attained) on the North Shore Channel (NSC) and North Branch Chicago River (NBCR) for WYs 2001, 2003, and 2008 applying the proposed guidelines for withdrawal of discretionary diversion at the Wilmette Pumping Station and operation of the Devon Avenue and Webster Avenue instream aeration stations.

Location	Waterway	2001	2003	2008
Simpson Street	NSC	100.00	100.00	92.75
Main Street	NSC	97.57	100.00	96.62
Foster Avenue	NSC	100.00	100.00	100.00
Addison Street	NBCR	100.00	100.00	100.00
Fullerton Avenue	NBCR	100.00	100.00	100.00
Division Street	NBCR	100.00	100.00	100.00
Kinzie Street	NBCR	100.00	100.00	100.00

In order to achieve these results the total discretionary diversion flow withdrawn at the WPS was 52.31, 47.85, and 47.19 cfs in WYs 2001, 2003, and 2008, respectively. Figure 4.13 shows the distribution of these discretionary diversion amounts at the WPS throughout the year.

Table 4.4 lists the number of hours with one blower on and two blowers on and the total blower hours for the Devon Avenue and Webster Avenue IASs for WYs 2001, 2003, and 2008. The lower flows in the representative "dry" year (WY 2003) require greater use of the IASs compared to the representative "normal" year (WY 2001). The low use of the IASs in WY 2008 is the result of the higher DO concentrations in the O'Brien WRP effluent in WY 2008 compared to the other WYs (see Figure 4.14).

The final conclusion of these simulations is that the procedures for "optimal" withdrawal of discretionary diversion at the WPS and operation of the Devon Avenue and Webster Avenue IASs described in Subsections 4.2.1 and 4.2.2, respectively, result in high attainment of the DO standards with a reasonable use of discretionary diversion and the IASs.

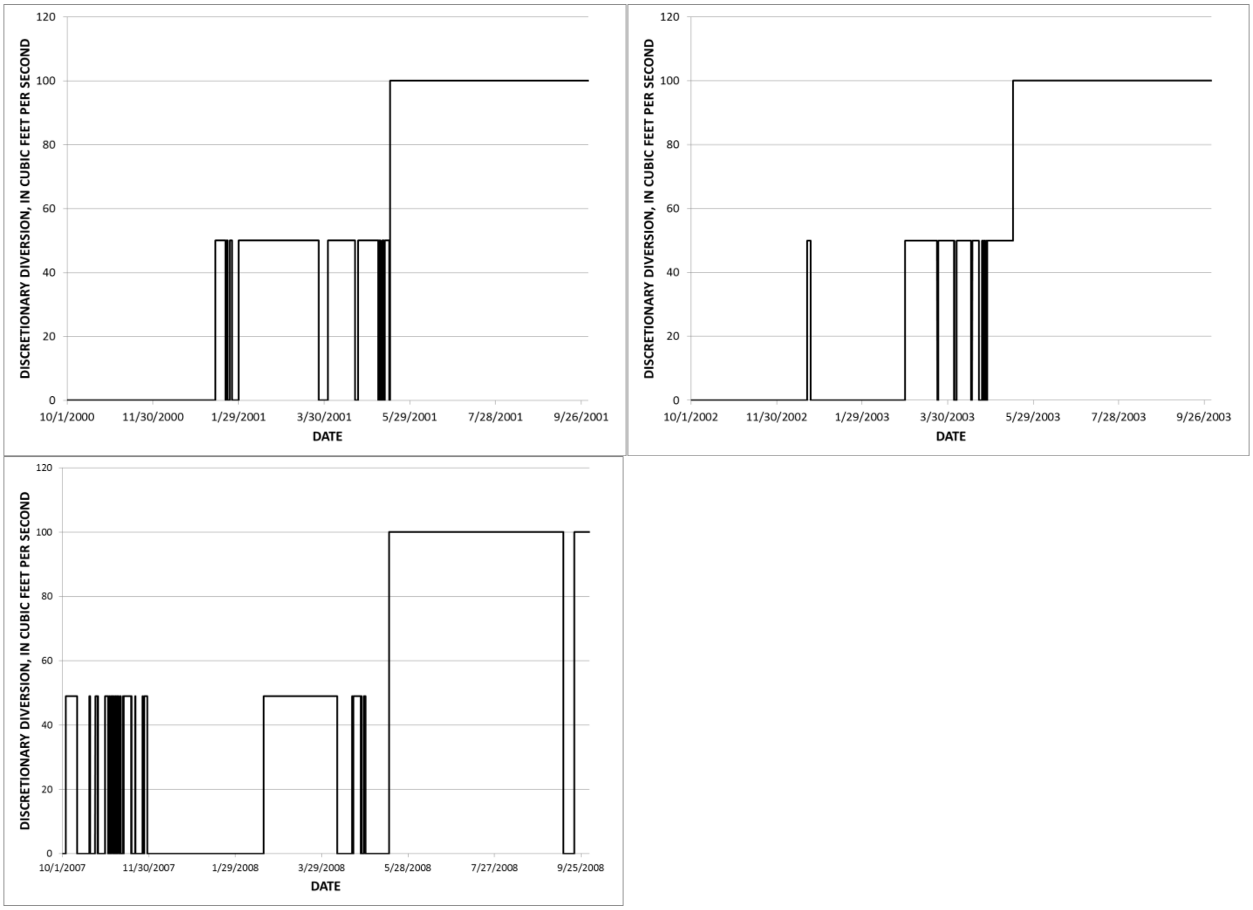

Figure 4.13. Distribution of "optimal" discretionary diversion at the Wilmette Pumping Station for Water Years 2001, 2003, and 2008.

Table 4.4. Number of hours with one blower on and two blowers on and total blower hours for the Devon Avenue and Webster Avenue instream aeration stations for Water Years 2001, 2003, and 2008.

Year	Devon Avenue			Webster Avenue		
	1 Blower	2 Blowers	Blower Hours	1 Blower	2 Blowers	Blower Hours
2001	1014	1194	3402	2303	509	3321
2003	1682	1854	5390	3608	283	4174
2008	86	35	156	301	3	307

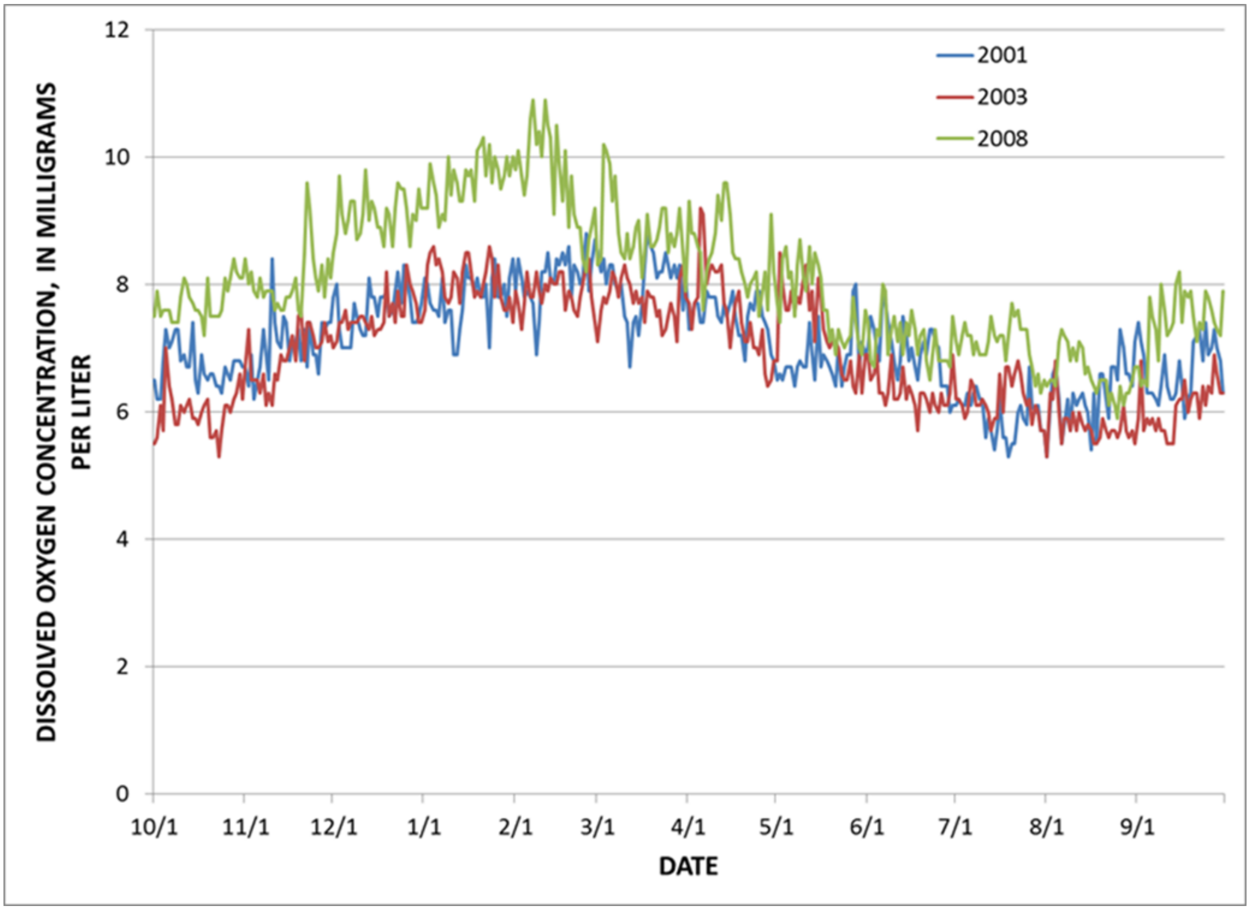

Figure 4.14. Dissolved oxygen concentration in the effluent from the O'Brien Water Reclamation Plant for Water Years 2001, 2003, and 2008.

4.3 Operational Guidance for Discretionary Diversion and Aeration to the Little Calumet River (north) and Calumet-Sag Channel

4.3.1 Discretionary Diversion Guidance and Limitations

Compared to the results presented in Chapter 3 the following changes in the procedures for withdrawal of discretionary diversion at the O'Brien L&D were made for the final operational guidance:

A) Melching et al. (2010) reported that the "calibrated" dispersion coefficient (D) for the reach of the Calumet River and Little Calumet River (north) between the O'Brien L&D and the Calumet WRP was 15 m^2/s. Whereas it was found that the DUFLOW model applied in the analysis reported in Chapter 3 utilized a D value for this reach equal to 1000 m^2/s, which was the value used in the preliminary calibration of the DUFLOW model reported in Alp and Melching (2006). Thus, in the simulations reported in this Chapter, D was set to 30 m^2/s (slightly higher than the calibrated value from Melching et al. (2010)). When D was set to 15 m^2/s computational instabilities were encountered that caused the DUFLOW model to "crash" for some of trial discretionary diversion values. Increasing D to 30 m^2/s did not result in any computational problems while only slightly changing the simulated DO concentrations in the subject reach.

B) Periods with simulated DO concentrations less than the at any time DO standard plus 0.3 mg/L (i.e. 3.8 mg/L in August-February and 5.3 mg/L in March-July) were identified at Conrail Railroad. Discretionary diversion then was applied to these periods. The "optimal" amount of discretionary diversion was determined on a monthly basis with the amount gradually increased at 25 cfs increments until either the at any time DO standard is fully attained for that month or the at any time DO standard is attained 95% of the time at Conrail and Central & Wisconsin railroads. Once 95% attainment is achieved the remaining discretionary diversion is dedicated to CRCW to raise Loomis Street on the SBCR to greater than 95% attainment of the at any time DO standard.

C) Under actual conditions in WY 2008, a flow reversal to Lake Michigan occurred at the O'Brien L&D from 17:30 on September 13 to 14:35 on September 16. Further, no discretionary diversion could be taken until 16:15 on September 20 when the interior water levels dropped to acceptable levels at the O'Brien L&D. Because the CSO flows to the CAWS were minimally affected by the Thornton Reservoir for the storm of September 13 to 16, 2008 (see Subsection 4.1.3), no discretionary diversion was allowed at the WPS between 0:00 of September 12 to 16:15 on September 20 in the simulations to determine of the optimal discretionary diversion for WY 2008.

4.3.2 Sidestream Elevated Pool Aeration Stations 2, 3, and 4

In these simulations SEPA Stations 2, 3, and 4 were operated as described in Section 3.3, especially Subsection 3.3.5.

4.3.3 Results

Table 4.5 lists the level of attainment of the at any time DO standard at various DO monitoring locations on the Little Calumet River (north) and Calumet-Sag Channel for WYs 2001, 2003, and 2008 applying the procedures described in Subsections 4.3.1 and 4.3.2. Table 4.6 lists the level of attainment of the 7-day mean of the daily minimum DO standard at various DO monitoring locations on the Little Calumet River (north) and Calumet-Sag Channel for WYs 2001, 2003, and 2008 applying the procedures described in Subsections 4.3.1 and 4.3.2. When the IDNR set the allowable annual discretionary diversion limit of 220 cfs a goal was to attain the DO standards at least 95% of the time at all locations in the CAWS. From Tables 4.5 and 4.6 it can be seen that this goal is achieved at all locations and years.

Table 4.5. Percentage of time the at any time dissolved oxygen standard is equaled or exceeded (i.e. attained) on the Little Calumet River (north) [LCRN] and Calumet-Sag Channel (CSAG) for WYs 2001, 2003, and 2008 applying the proposed guidelines for withdrawal of discretionary diversion at the O'Brien Lock and Dam and operation of Sidestream Elevated Pool Aeration stations 2, 3, and 4.

Location	Waterway	2001	2003	2008
Conrail Railroad	LCRN	96.82	97.32	98.14
Central & Wisconsin Railroad	LCRN	95.71	96.48	98.20
Halsted Street	LCRN	100.00	100.00	99.53
Division Street	CSAG	100.00	100.00	100.00
Kedzie Street	CSAG	100.00	99.98	100.00
Cicero Avenue	CSAG	99.92	99.92	100.00
Harlem Avenue	CSAG	100.00	99.95	100.00
Southwest Highway	CSAG	100.00	99.93	100.00
104th Avenue	CSAG	100.00	99.89	100.00
Route 83	CSAG	100.00	99.91	100.00

Table 4.6. Percentage of days the 7-day mean of the daily minimum dissolved oxygen standard is equaled or exceeded (i.e. attained) on the Little Calumet River (north) [LCRN] and Calumet-Sag Channel (CSAG) for WYs 2001, 2003, and 2008 applying the proposed guidelines for withdrawal of discretionary diversion at the O'Brien Lock and Dam and operation of Sidestream Elevated Pool Aeration stations 2, 3, and 4.

Location	Waterway	2001	2003	2008
Conrail Railroad	LCRN	100.00	96.12	96.14
Central & Wisconsin Railroad	LCRN	99.03	100.00	95.17
Halsted Street	LCRN	100.00	100.00	99.03
Division Street	CSAG	100.00	100.00	100.00
Kedzie Street	CSAG	100.00	100.00	100.00
Cicero Avenue	CSAG	100.00	100.00	100.00
Harlem Avenue	CSAG	100.00	100.00	100.00
Southwest Highway	CSAG	100.00	100.00	100.00
104th Avenue	CSAG	100.00	100.00	100.00
Route 83	CSAG	100.00	100.00	100.00

In order to achieve these results the total discretionary diversion flow withdrawn at the O'Brien L&D was 29.39, 35.39, and 78.36 cfs in WYs 2001, 2003, and 2008, respectively. Figure 4.15 shows the distribution of these discretionary diversion amounts at the O'Brien L&D throughout the year. The high discretionary diversion at the O'Brien L&D in September 2008 was taken to try to counteract the lingering effects of the September 13-16, 2008, storm on the Calumet River system. This is similar to the actual withdrawal of discretionary diversion at the O'Brian L&D during September 2008.

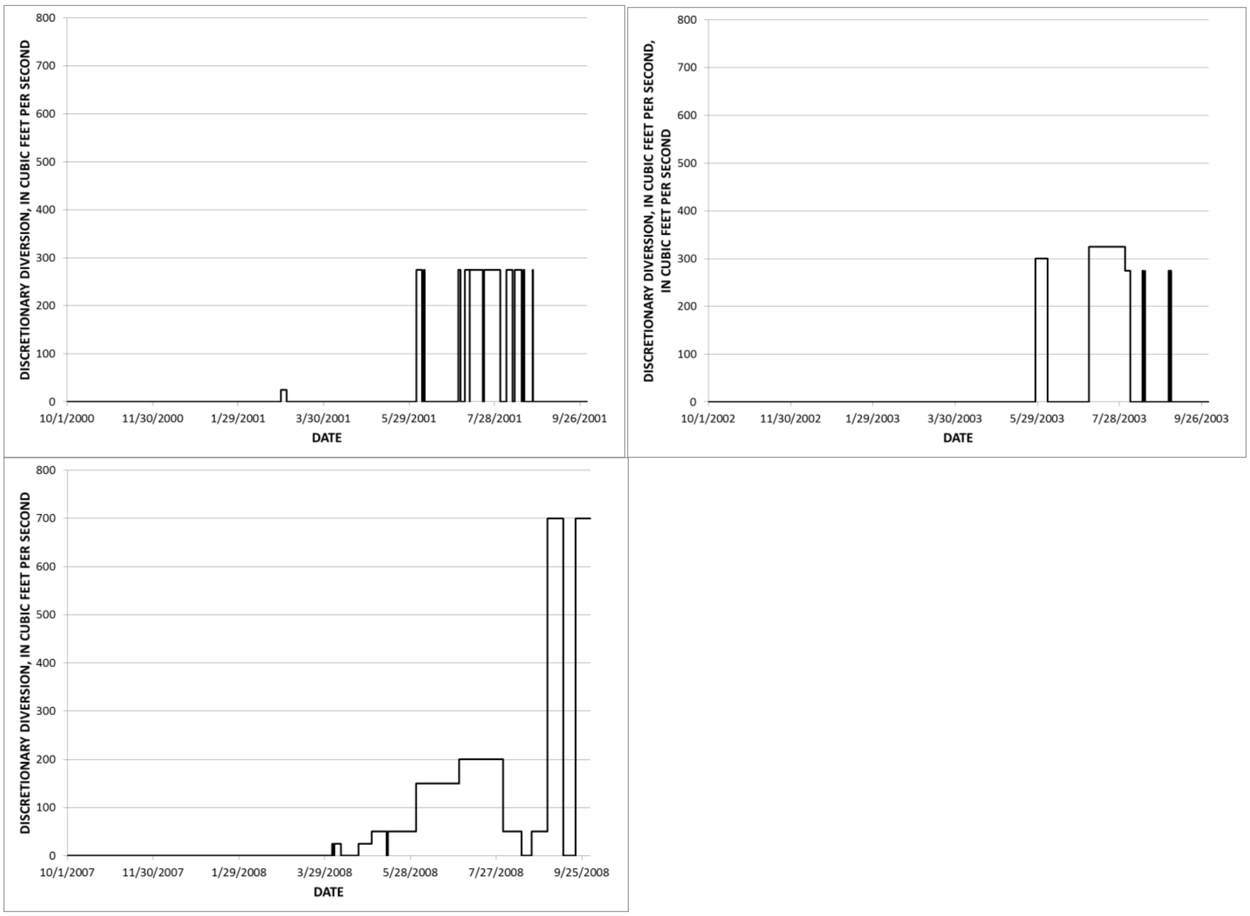

Figure 4.15. Distribution of "optimal" discretionary diversion at the O'Brien Lock & Dam for Water Years 2001, 2003, and 2008.

Table 4.7 lists the number of hours with one pump on, two pumps on, and three pumps on and the total pump hours for SEPA stations 2, 3, and 4 for WYs 2001, 2003, and 2008.

The final conclusion of these simulations is that the procedures for "optimal" withdrawal of discretionary diversion at the O'Brien L&D and operation of SEPA stations 2, 3, and 4 described in Subsections 4.3.1 and 4.3.2, respectively, result in high attainment of the DO standards with a reasonable use of discretionary diversion and the SEPA stations.

Table 4.7. Number of hours with one pump on, two pumps on, and three pumps on and total pump hours for Sidestream Elevated Pool Aeration (SEPA) stations 2, 3, and 4 for Water Years 2001, 2003, and 2008.

Year	1 Pump	2 Pumps	3 Pumps	Pump-hours
SEPA 2				
2001	5044	92		5228
2003	5134	2		5138
2008	5136	0		5136
SEPA 3				
2001	3390	245	44	4012
2003	3608	55	9	3745
2008	3661	11	0	3683
SEPA 4				
2001	3294	371	21	4099
2003	3657	35	16	3775
2008	3670	2	0	3674

4.4 Operational Guidance for Discretionary Diversion and Aeration to the Chicago River Main Stem, South Branch Chicago River, and Chicago Sanitary and Ship Canal

4.4.1 Discretionary Diversion Guidance and Limitations

After the “optimal” withdrawal of discretionary diversion at the WPS and the “optimal” operations of the Devon Avenue and Webster Avenue IASs were determined, a simulation was done with these “optimal” procedures and no discretionary diversion at the CRCW. The travel time from the CRCW to Loomis Street is approximately 2 days. Thus, when low DO concentrations at Loomis Street are measured it is too late to withdraw discretionary diversion at the CRCW to mitigate the low DO concentrations at Loomis Street. Thus, relations between DO concentrations less than the at any time DO standard at Loomis Street and DO concentrations at Kinzie Street were sought to indicate times when discretionary diversion should be withdrawn at the CRCW. Figure 4.16 shows the simulated DO concentrations at Kinzie Street on the NBCR (acting as a surrogate for the existing DO monitor at Ohio Street) and Loomis Street on the SBCR for each month in WY 2001. From Figure 4.16 the following rules for identifying times in WY 2001 when discretionary diversion at CRCW is needed were developed:

A) In January and February 2001 DO concentrations less than the at any time DO standard (3.5 mg/L) at Loomis Street seem to be related to DO concentrations at Kinzie Street less than 5.5 mg/L. Therefore, discretionary diversion was withdrawn at the CRCW when DO Kinzie Street is less than 5.5 mg/L (i.e. the "trigger" concentration) in January and February 2001. Although no periods with DO less than the at all times standard occur in October-December for consistency in the operational guidance in the fall and winter months discretionary diversion also was withdrawn at the CRCW when DO Kinzie Street is less than 5.5 mg/L in October-December 2000.

B) In March 2001 DO concentrations less than the at any time DO standard (5 mg/L) at Loomis Street seem to be related to DO concentrations at Kinzie Street less than 7.0 mg/L. Therefore, discretionary diversion was withdrawn at the CRCW when DO Kinzie Street is less than 7.0 mg/L (i.e. "trigger") in March 2001.

C) In April-July 2001 DO concentrations less than the at any time DO standard (5 mg/L) at Loomis Street seem to be related to DO concentrations at Kinzie Street less than 6.5 mg/L. Therefore, discretionary diversion was withdrawn at the CRCW when DO Kinzie Street is less than 6.5 mg/L (i.e. "trigger") in April-July 2001.

Figure 4.16. Simulated dissolved oxygen (DO) concentration for Water Year 2001 at Loomis Street and Kinzie Street and apparent "trigger" DO concentration at Kinzie Street that results in DO concentrations less than the at any time DO standard at Loomis Street.

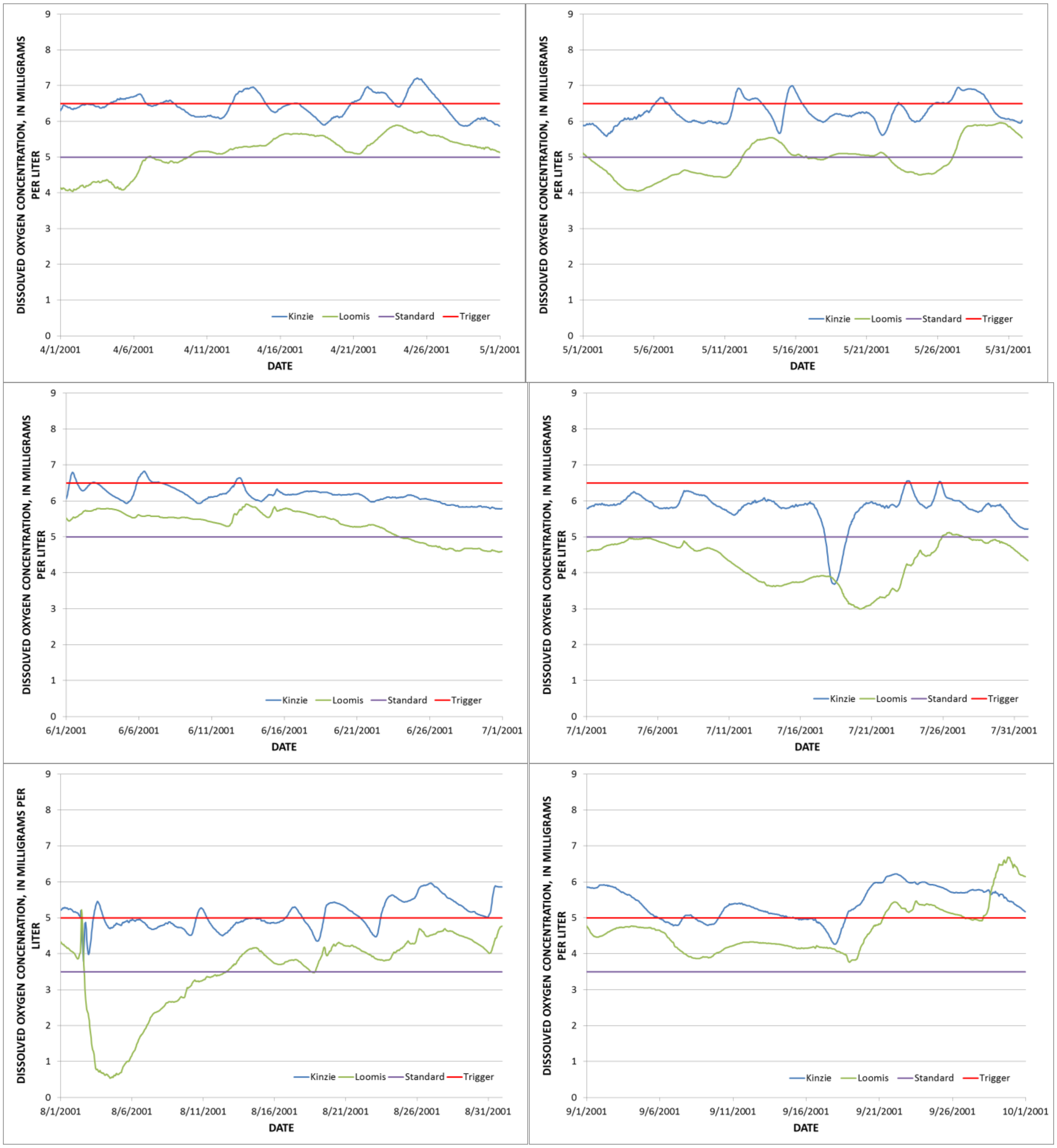

Figure 4.16. (cont.) Simulated dissolved oxygen (DO) concentration for Water Year 2001 at Loomis Street and Kinzie Street and apparent "trigger" DO concentration at Kinzie Street that results in DO concentrations less than the at any time DO standard at Loomis Street.

D) In August and September 2001 DO concentrations less than the at any time DO standard (3.5 mg/L) at Loomis Street seem to be related to DO concentrations at Kinzie Street less than 5.0 mg/L. Therefore, discretionary diversion was withdrawn at the CRCW when DO Kinzie Street is less than 5.0 mg/L (i.e. “trigger”) in April-July 2001.

The “optimal” amount of discretionary diversion was determined on a monthly basis with the amount gradually increased at 25 cfs increments until either the at any time DO standard is fully attained for that month or the at any time DO standard is attained 95% of the time at Loomis Street. The remaining total discretionary diversion for the year is then be applied at the CRCW or O’Brien L&D such that the minimum level of attainment of the at any time DO standard is maximized throughout the CAWS.

Under actual conditions on August 2, 2001 a flow reversal to Lake Michigan at the CRCW occurred as a result of heavy storm (CSO flows) to the CAWS. With Stage 1 of the McCook Reservoir operational these heavy storm flows would be captured by the reservoir. Thus, no flow reversals would occur and, in fact, it would be feasible to take discretionary diversion during this period for which it was impossible to take discretionary diversion during actual conditions. Thus, discretionary diversion also was applied to this period in August 2001.

Figure 4.17 shows the simulated DO concentrations at Kinzie Street on the NBCR (acting as a surrogate for the existing DO monitor at Ohio Street) and Loomis Street on the SBCR for each month in WY 2003. From Figure 4.17 the following adjustments to the rules for identifying times when discretionary diversion at CRCW is needed (developed based on WY 2001) were applied:

A) The DO concentration at the beginning of March 2003 is less than the at any time DO standard (5.0 mg/L) at Loomis Street. Thus, to account for the 2 day travel time from the

CRCW to Loomis Street discretionary diversion should be withdrawn at CRCW if the DO concentration at Kinzie Street is less than 7.0 mg/L any time between 0:00 on February 26th and the end of February.

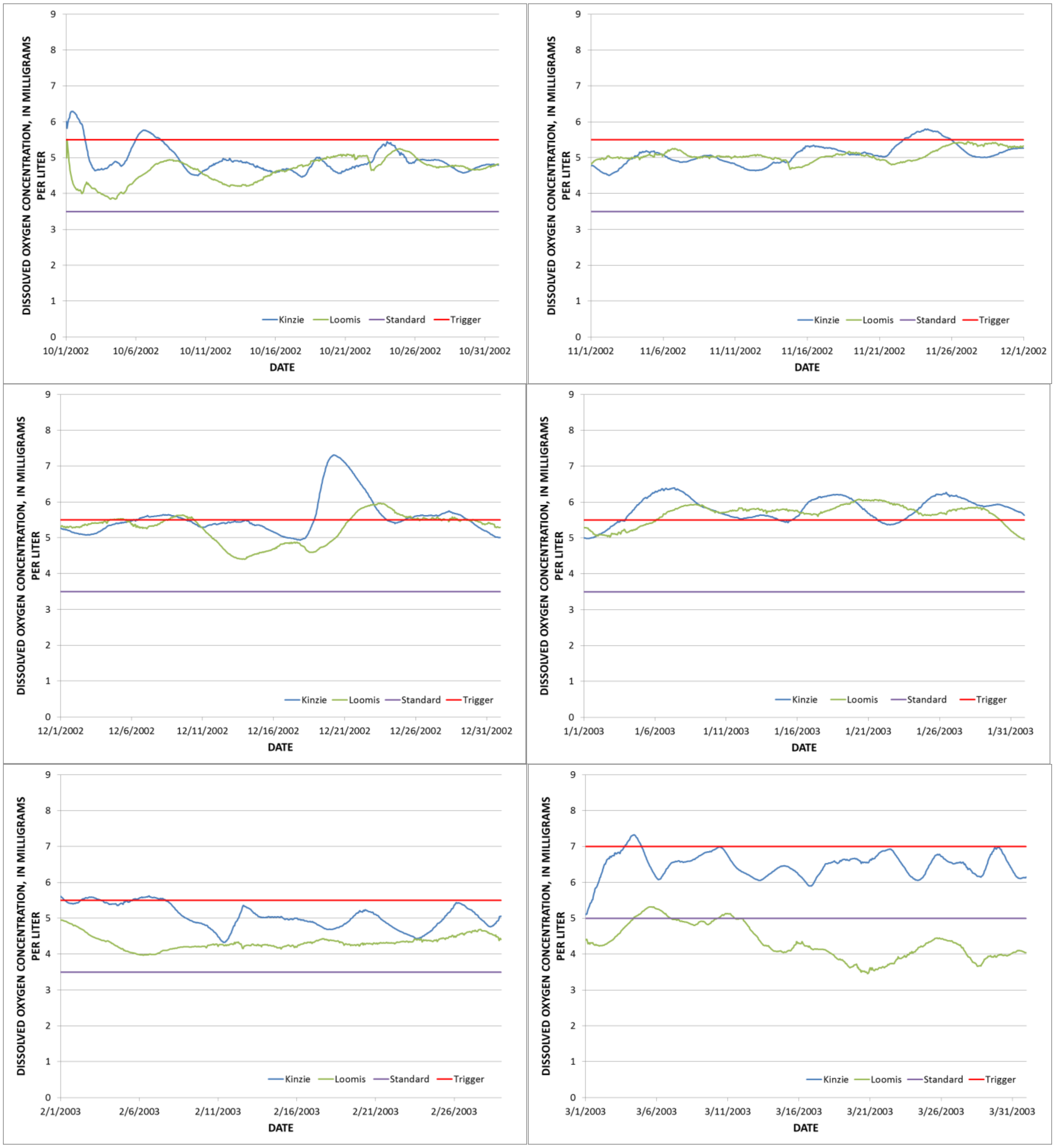

Figure 4.17. Simulated dissolved oxygen (DO) concentration for Water Year 2003 at Loomis Street and Kinzie Street and apparent "trigger" DO concentration at Kinzie Street that results in DO concentrations less than the at any time DO standard at Loomis Street.

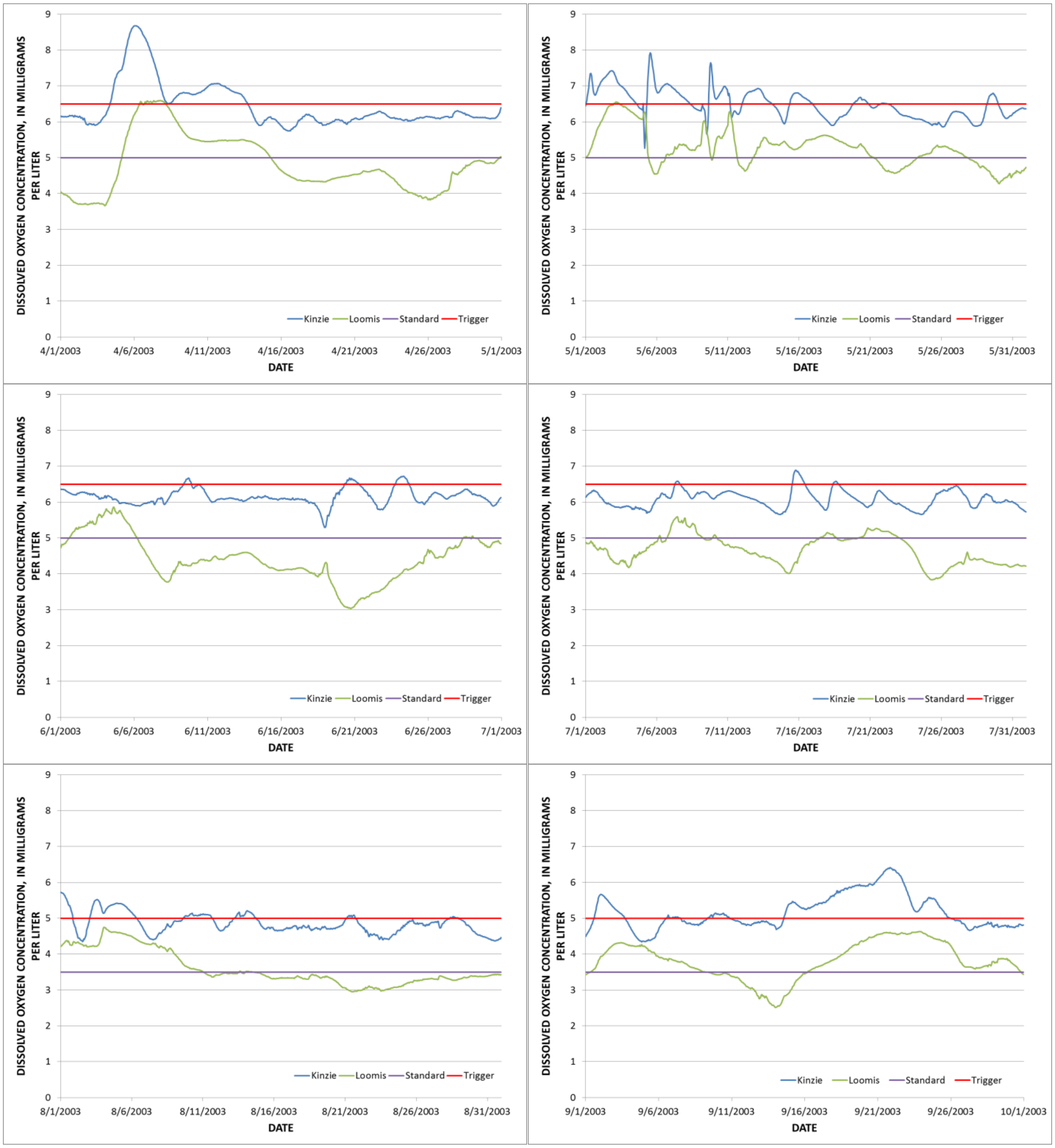

Figure 4.17. (cont.) Simulated dissolved oxygen (DO) concentration for Water Year 2003 at Loomis Street and Kinzie Street and apparent "trigger" DO concentration at Kinzie Street that results in DO concentrations less than the at any time DO standard at Loomis Street.

B) For WY 2003 no periods with DO concentrations less than the at any time DO standard (3.5 mg/L) occurred at Loomis Street. Thus, it was decided to not apply the less than 5.5 mg/L "trigger" at Kinzie Street to October-February for WY 2003.

The "optimal" amount of discretionary diversion was determined on a monthly basis with the amount gradually increased at 25 cfs increments until either the at any time DO standard is fully attained for that month or the at any time DO standard is attained 95% of the time at Loomis Street. The remaining total discretionary diversion for the year would then be applied at the CRCW or O'Brien L&D such that the minimum level of attainment of the at any time DO standard is maximized throughout the CAWS.

Figure 4.18 shows the simulated DO concentrations at Kinzie Street on the NBCR (acting as a surrogate for the existing DO monitor at Ohio Street) and Loomis Street on the SBCR for each month in WY 2008. From Figure 4.18 it is clear that the operational guidance for taking discretionary diversion at the CRCW used in March to September for both WYs 2001 and 2003 should work well for WY 2008. Also, from Figure 4.18 it is clear that there is no need for discretionary diversion at the CRCW in the months of October to February as was the case for WY 2003.

The "optimal" amount of discretionary diversion was determined on a monthly basis with the amount gradually increased at 25 cfs increments until either the at any time DO standard is fully attained for that month or the at any time DO standard is attained 95% of the time at Loomis Street. The remaining total discretionary diversion for the year would then be applied at the

CRCW or O'Brien L&D such that the minimum level of attainment of the at any time DO standard is maximized throughout the CAWS.

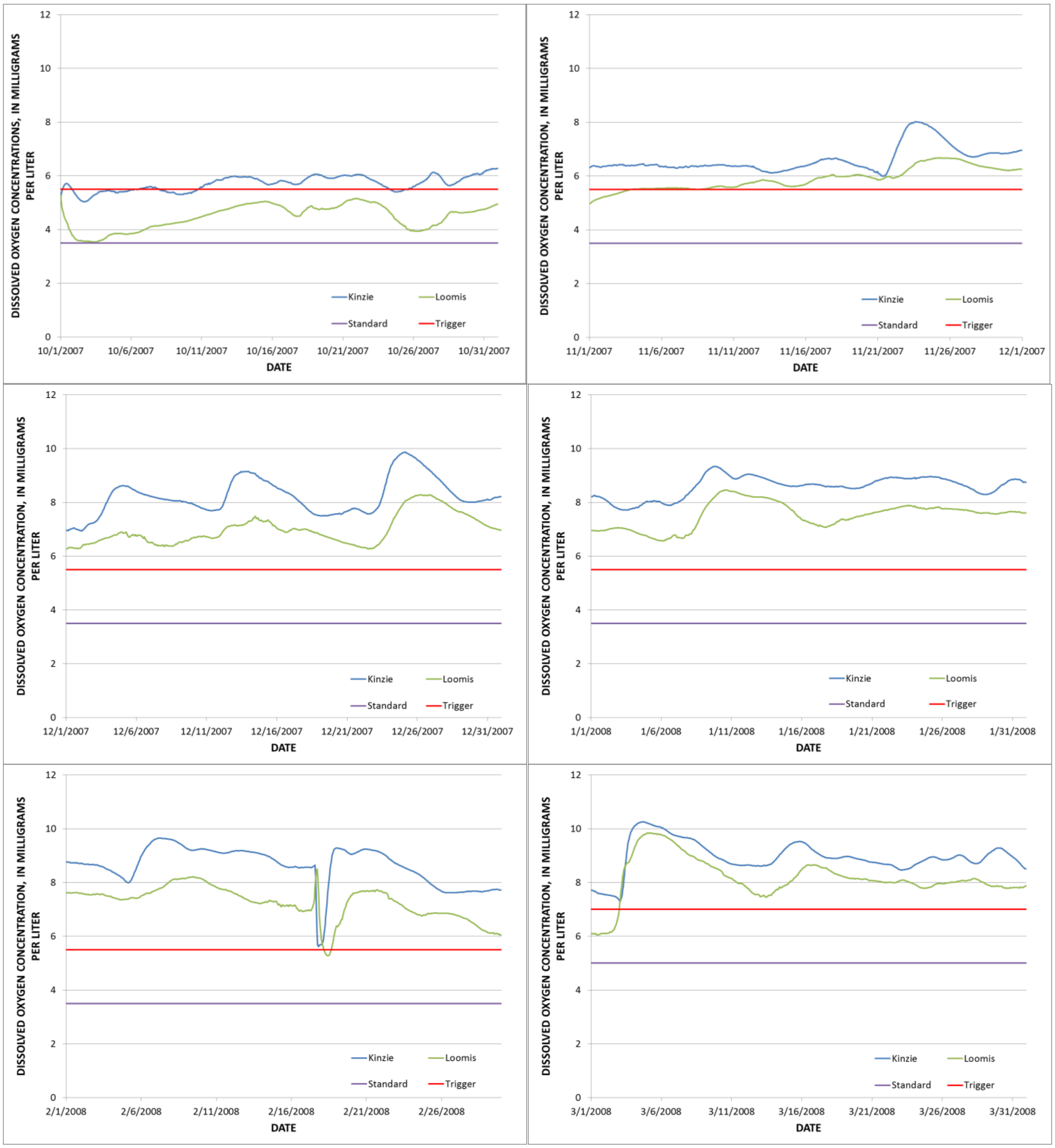

Figure 4.18. Simulated dissolved oxygen (DO) concentration for Water Year 2008 at Loomis Street and Kinzie Street and apparent "trigger" DO concentration at Kinzie Street that results in DO concentrations less than the at any time DO standard at Loomis Street.

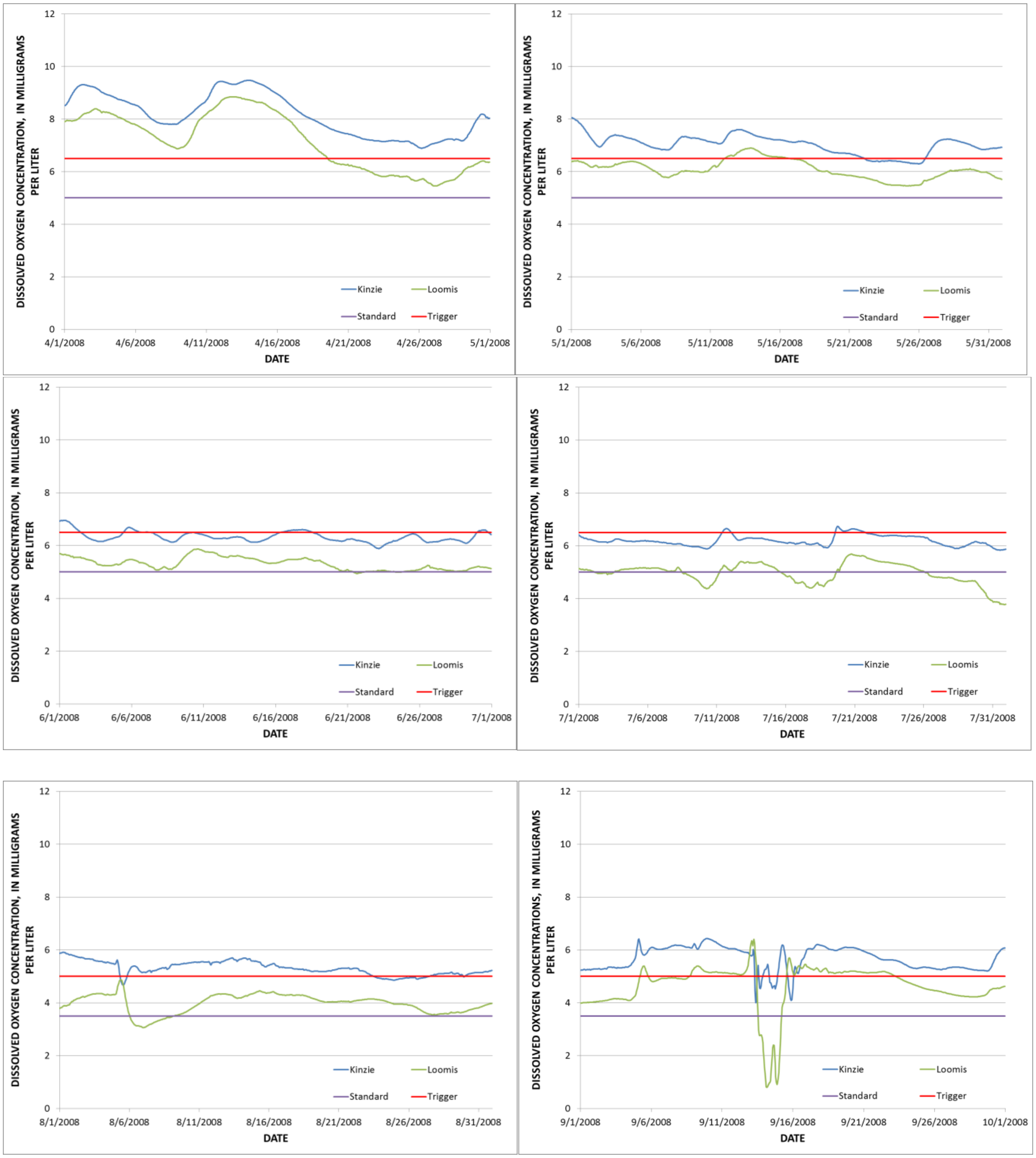

Figure 4.18. (cont.) Simulated dissolved oxygen (DO) concentration for Water Year 2008 at Loomis Street and Kinzie Street and apparent "trigger" DO concentration at Kinzie Street that results in DO concentrations less than the at any time DO standard at Loomis Street.

Under actual conditions in WY 2008, a flow reversal to Lake Michigan occurred at the CRCW from 10:00 on September 13 to 11:30 on September 15. Further, no discretionary diversion could be taken until 9:22 on September 20 when the interior water levels dropped to acceptable levels at the CRCW. Because the CSO flows to the CAWS were minimally affected by Stage 1 of the McCook Reservoir for the storm of September 13 to 16, 2008 (see Subsection 4.1.3), no discretionary diversion was allowed at the CRCW between 0:00 of September 13 to 9:22 on September 20 in the simulations to determine of the optimal discretionary diversion for WY 2008.

4.4.2 Sidestream Elevated Pool Aeration Station 5

The DO monitoring location for the operation of SEPA 5 is the LCW approximately 20 hours travel time from SEPA 5. It will be operated using the same sort of "modified traditional" approach used for SEPA stations 3 and 4. That is, one pump will run continuously from May 1 to September 30 with additional pumps operated as needed as described in Chapter 3.

One difference in the operation of SEPA 5 compared to SEPA stations 3 and 4 is that the DO concentration at its monitoring point (LCW) drops below 0.9 mg/L above the at any time DO standard outside the period of continuous operation of 1 pump (i.e. October through April). For these periods when the DO concentration at the LCW on the CSSC drops below 0.9 mg/L above the at any time DO standard (i.e. less than 4.4 mg/L for October through February and less than 5.9 mg/L for March through April) turn on one pump at SEPA 5, and this pump should remain on until the DO concentration exceeds 0.9 mg/L above the DO standard. If the DO concentration at the LCW continues to decrease to less than 0.6 mg/L above the at any time DO standard (i.e. less than 4.1 mg/L for October through February and less than 5.6 mg/L for March through April), a second pump should be turned on at SEPA 5, and this pump should remain on until the

DO concentration exceeds 0.6 mg/L above the DO standard. Finally, if the DO concentration at the LCW continues to decrease to less than 0.3 mg/L above the at any time DO standard (i.e. less than 3.8 mg/L for October through February and less than 5.3 mg/L for March through April), a third pump should be turned on at SEPA 5, and this pump should remain on until the DO concentration exceeds 0.3 mg/L above the DO standard.

4.4.3 Results

Table 4.8 lists the level of attainment of the at any time DO standard at various DO monitoring locations on the SBCR and CSSC for WYs 2001, 2003, and 2008 applying the procedures described in Subsections 4.4.1 and 4.4.2. Table 4.9 lists the level of attainment of the 7-day mean of the daily minimum DO standard at various DO monitoring locations on the SBCR and CSSC for WYs 2001, 2003, and 2008 applying the procedures described in Subsections 4.4.1 and 4.4.2. When the IDNR set the allowable annual discretionary diversion limit of 220 cfs a goal was to attain the DO standards at least 95% of the time at all locations in the CAWS. From Tables 4.8 and 4.9 it can be seen that this goal is achieved at nearly all locations and years. The only exception is that the 7-day mean of the daily minimums DO standard is not attained on 95% of the days at Loomis Street for each WY. For WY 2008 the reason the 95% attainment goal could not be met for the 7-day mean of daily minimum DO standard at Loomis Street is that half of the non-attainment occurs between September 14 and 20 and nothing could be done about this because discretionary diversion could only be taken beginning at 9:22 on September 20. That is, the 7-day mean is affected by several days with no discretionary diversion during this period, and, thus, there is no way to raise the mean above the DO standard. If the non-attainment in September 2008 is ignored the 7-day mean of daily minimum DO concentrations exceeds 4 mg/L on 96.50% of the days. For WYs 2001 and 2003 since the year specific optimization focused on meeting the at any time DO standard, it is not surprising that the 7-day mean of daily minimum DO standard was not attained on 95% of the days. However, this is adjusted for by dedicating more discretionary diversion to August and September in the development of the final “optimal” guidance in Chapter 5.

Table 4.10 lists the levels of attainment of the various aspects of the General Use waters DO standards applicable to the Chicago River main stem at Clark Street. For WYs 2001 and 2003 there appears to be a problem meeting the criterion that during the period of August through February the daily mean DO averaged over 30 days meet or exceed 5.5 mg/L. For WY 2001 the problem period is September 15-30. Thus, in the development of the final guidance more discretionary diversion should be dedicated to August and September to improve the attainment with the 30-day mean DO standard in WY 2001.

Table 4.8. Percentage of time the at any time dissolved oxygen standard is equaled or exceeded (i.e. attained) on the South Branch Chicago River (SBCR) and Chicago Sanitary and Ship Canal (CSSC) for WYs 2001, 2003, and 2008 applying the proposed guidelines for withdrawal of discretionary diversion at the Chicago River Controlling Works and operation of Sidestream Elevated Pool Aeration station 5.

Location	Waterway	2001	2003	2008
Jackson Boulevard	SBCR	99.74	100.00	99.89
Loomis Street	SBCR	95.89	96.94	99.27
Cicero Avenue	CSSC	98.89	99.98	99.42
Baltimore & Ohio Railroad	CSSC	99.61	100.00	99.65
Route 83	CSSC	99.43	100.00	99.45
River Mile 302.6	CSSC	99.93	100.00	99.81
Romeoville Road	CSSC	99.53	100.00	99.74
Lockport Controlling Works	CSSC	99.52	99.93	99.72

Table 4.9. Percentage of days the 7-day mean of the daily minimum dissolved oxygen standard is equaled or exceeded (i.e. attained) on the South Branch Chicago River (SBCR) and Chicago Sanitary and Ship Canal (CSSC) for WYs 2001, 2003, and 2008 applying the proposed guidelines for withdrawal of discretionary diversion at the Chicago River Controlling Works and operation of Sidestream Elevated Pool Aeration station 5.

Location	Waterway	2001	2003	2008
Jackson Boulevard	SBCR	100.00	100.00	100.00
Loomis Street	SBCR	94.66	84.47	93.24
Cicero Avenue	CSSC	97.77	97.21	98.33
Baltimore & Ohio Railroad	CSSC	100.00	100.00	100.00
Route 83	CSSC	99.16	100.00	100.00
River Mile 302.6	CSSC	100.00	100.00	100.00
Romeoville Road	CSSC	100.00	100.00	100.00
Lockport Controlling Works	CSSC	99.72	100.00	100.00

Table 4.10. Percentage of time meeting or exceeding (i.e. attaining) the various aspects of the General Use dissolved oxygen standards applicable to the Chicago River main stem at Clark Street for Water Years 2001, 2003, and 2008.

Criterion	2001	2003	2008
All times	100.00	100.00	99.87
7-day Mean	100.00	100.00	100.00
7-day Mean of Daily Minimum	100.00	100.00	100.00
30-day Mean	91.26	88.52	100.00

For WY 2003 the problem periods are October 30 to November 15 and February 23-26, however, this may be the result of model inaccuracy rather than defining the need for discretionary diversion during these periods. As shown in Melching et al. (2010) and Melching and Liang (2013) the DUFLOW model has a tendency to underpredict the measured DO concentrations in the CAWS during the late Fall and Winter. The measured DO concentration data at Clark Street from August 1998 through May 2017 indicate that only 203 of 12,996 values in October, 176 of 12,773 values in November, 36 of 12,217 values in December, 0 of 12,473 values in January, and 0 of 11,384 values in February were less than 5.5 mg/L. Thus, it is highly unlikely that the 30-day mean of DO concentrations would be less than 5.5 mg/L in October through February and WY 2003 actually would achieve full attainment with the DO criterion of the 30-day mean of DO concentrations.

In order to achieve these results the total discretionary diversion flow withdrawn at the CRCW was 137.43, 136.76, and 23.12 cfs in WYs 2001, 2003, and 2008, respectively. Figure 4.19 shows the distribution of these discretionary diversion amounts at the CRCW throughout the year.

The resulting total discretionary diversion for WYs 2001, 2003, and 2008 is 219.67, 220.01, and 156.63 cfs, respectively. For WY 2008 a lot of extra water remains that may be applied to improve the attainment of the 7-day mean of the daily minimum DO standards, particularly in August. However, many of the simulated DO concentrations not attaining the at any time DO standard at all locations in the CAWS for WY 2008 occur during the periods in September when no discretionary diversion can be withdrawn.

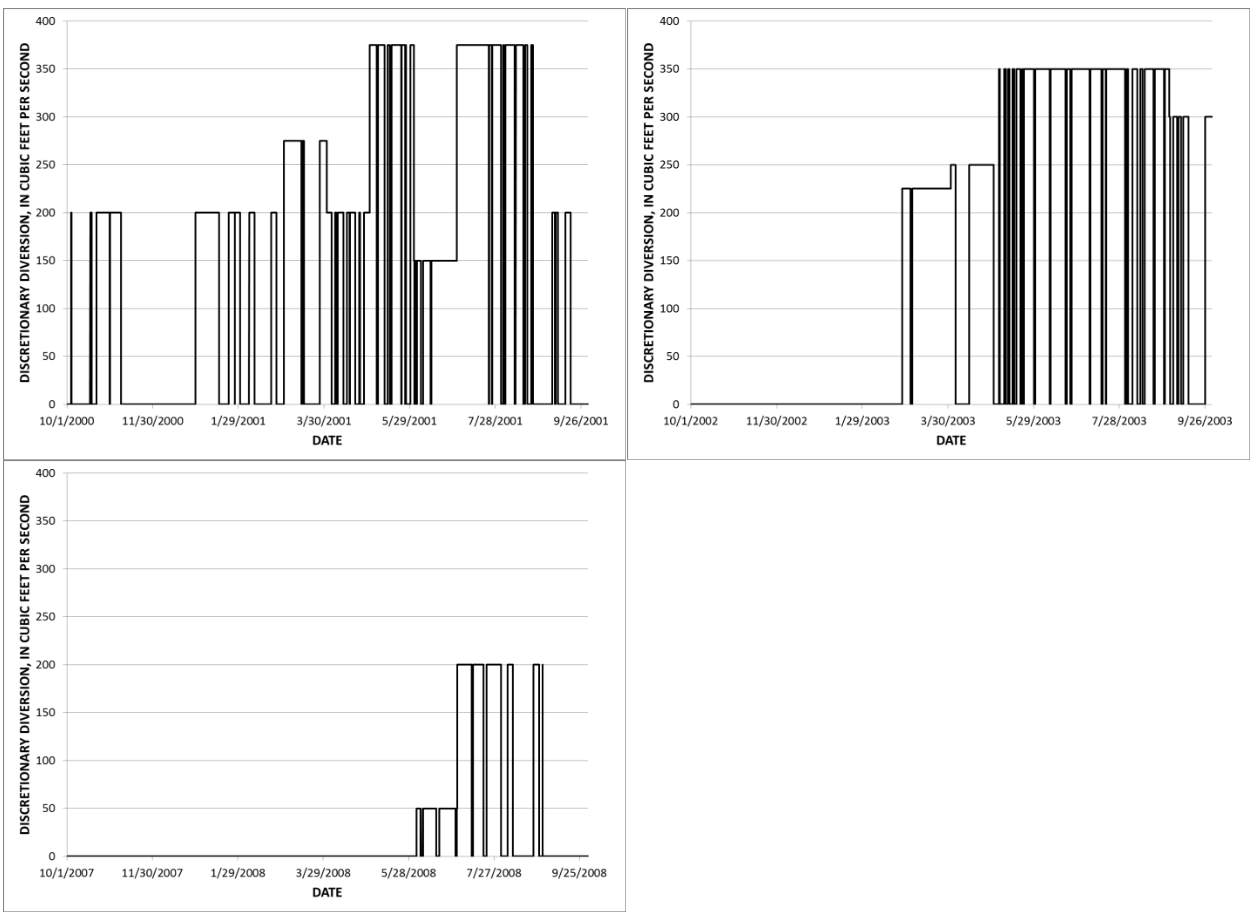

Figure 4.19. Distribution of “optimal” discretionary diversion at the Chicago River Controlling Works for Water Years 2001, 2003, and 2008.

Table 4.11 lists the number of hours with one pump on, two pumps on, and three pumps on and the total pump hours for SEPA 5 for WYs 2001, 2003, and 2008.

Table 4.11. Number of hours with one pump on, two pumps on, and three pumps on and total pump hours for Sidestream Elevated Pool Aeration station 5 for Water Years 2001, 2003, and 2008.

Year	1 Pump	2 Pumps	3 Pumps	Pump-hours
2001	3607	32	100	3971
2003	3662	29	53	3879
2008	3611	25	36	3769

The final conclusion of these simulations is that the procedures for “optimal” withdrawal of discretionary diversion at the CRCW and operation of SEPA 5 described in Subsections 4.4.1 and 4.4.2, respectively, result in high attainment of the at any time DO standard with a reasonable use of discretionary diversion and the SEPA 5. In the development of the final guidance for withdrawal of discretionary diversion consideration must be given to improving attainment of the other DO standards without greatly sacrificing attainment of the at any time DO standard.

Chapter 5 Final Guidance for Withdrawal of Discretionary Diversion

Table 5.1 lists the "optimal" monthly discretionary diversion values for the CRCW and O'Brien L&D found on a year specific basis in Chapter 4. The key goal of the study reported in this Chapter is to find compromise discretionary diversion amounts among the values in Table 5.1 that yield high levels of attainment of the at any time DO standard at all locations in the CAWS for all three representative test years. Again the target is to achieve attainment of all the DO standards at least 95% of the time. Two limitations (discussed in the next Section) must be considered and dealt with in order to achieve the overall goals in the development of the operational guidance for withdrawal of discretionary diversion.

Table 5.1. "Optimal" monthly discretionary diversion values (in cfs) for Water Years 2001, 2003, and 2008 at the Chicago River Controlling Works and O'Brien Lock & Dam determined in Chapter 4.

Month	Chicago River Controlling Works			O'Brien Lock & Dam		
	2001	2003	2008	2001	2003	2008
October	200					
November	200					
December	200					
January	200					
February	200					
March	275	225		25		
April	200	250				25
May	375	350			300	50
June	150	350	50	275	300	150
July	375	350	200	275	325	200
August	375	350	200	275	275	50
September	200	300	200		275	700

5.1 Limitations for the Development of the Final Guidance

5.1.1 Need for Discretionary Diversion at the CRCW and O'Brien L&D in October-February

Section 4.4.1 indicated that for WY 2001 discretionary diversion was needed in January and February 2001 and the proposed operational rules were extended into October-December 2000. However, for WYs 2003 and 2008 no discretionary diversion was needed in October-February. Thus, it is necessary to determine whether discretionary diversion actually will be needed in October through February. As mentioned earlier, results in Melching et al. (2010) and Melching and Liang (2013) indicate the DUFLOW model has a tendency to underpredict the measured DO concentrations in the CAWS during the late Fall and Winter. The measured DO concentration data at Loomis Street from August 1998 through May 2017 indicate that only 5 of 12,245 values in October, 106 of 11,580 values in November, 0 of 12,209 values in December, 0 of 11,912 values in January, and 0 of 10,162 values in February were less than 3.5 mg/L. Thus, DO concentrations less that the at any time DO standard of 3.5 mg/L are extremely rare in October through February, and, thus, developing discretionary diversion guidance to deal with these rare occurrences is not appropriate. That is, it will be more effective to concentrate the available discretionary diversion in the Spring and Summer months that are more prone to non-attainment of the DO standards. In this chapter any simulated DO concentrations at Loomis Street less than 3.5 mg/L in October-February are omitted from the computed percentage of time attaining the DO standards, and also any 30-day mean of DO concentrations at Clark Street less than 5.5 mg/L in October-February are omitted from the computed percentage of time attaining the DO standards.

For the Little Calumet River (north) between the O'Brien L&D and the Calumet WRP the simulations for the test years indicated that no discretionary diversion was needed at the O'Brien L&D for October-February. However, this does not mean that discretionary diversion might not be needed in these months for other years. Thus, the measured DO concentration data at Conrail Railroad from July 2001 through March 2004 and at Central & Wisconsin Railroad from July 2001 through May 2017 were reviewed. The data at Conrail Railroad indicate that only 21 of 2,026 values (1.04%) in October, 0 of 2,160 values in November, 0 of 2,232 values in December, 0 of 1,667 values in January, and 0 of 1,367 values in February were less than 3.5 mg/L. The data at Central & Wisconsin Railroad indicate that 0 of 11,148 values in October, 0 of 11,396 values in November, 0 of 11,138 values in December, 0 of 10,801 values in January, and 0 of 9,152 values in February were less than 3.5 mg/L. Thus, DO concentrations less that the at any time DO standard of 3.5 mg/L are extremely rare in October through February, and, thus, developing discretionary diversion guidance to deal with these rare occurrences is not appropriate. That is, it will be more effective to concentrate the available discretionary diversion in the Spring and Summer months that are more prone to non-attainment of the DO standards.

5.1.2 Consideration of Other Dissolved Oxygen Criteria

As noted previously the year specific optimization focused on meeting the at any time DO standard, and it is not surprising that the 7-day mean of daily minimum DO standard was not attained on 95% of the days. This means that in the final guidance on discretionary diversion equal importance needs to be placed on meeting the 7-day mean of daily minimum and 30-day mean DO standards at least 95% of the time. The practical result of this emphasis is that more discretionary diversion should be applied at the CRCW in August and September.

5.2 Results

5.2.1 North Shore Channel and North Branch Chicago River

No changes in the guidance for withdrawal of discretionary diversion at the WPS or the operation of the Devon Avenue and Webster Avenue IASs were made. Thus, the results reported in Subsection 4.2.3 are valid for the final guidance procedures.

5.2.2 Little Calumet River (north) and Calumet-Sag Channel

Table 5.2 lists the level of attainment of the at any time DO standard at various DO monitoring locations on the Little Calumet River (north) and Calumet-Sag Channel for WYs 2001, 2003, and 2008 applying the procedures described in Subsections 4.3.1 and 4.3.2 with the monthly discretionary diversion flows made consistent for all years. Table 5.3 lists the level of attainment of the 7-day mean of the daily minimum DO standard at various DO monitoring locations on the Little Calumet River (north) and Calumet-Sag Channel for WYs 2001, 2003, and 2008 applying the procedures described in Subsections 4.3.1 and 4.3.2 with the monthly discretionary diversion flows made consistent for all years. From Tables 5.2 and 5.3 it can be seen that the goal of 95% attainment of the DO standards is achieved at all locations and years except for the 7-day mean of daily minimum DO standard for Central & Wisconsin Railroad for WY 2008. The problem period for WY 2008 is September 16-28, which is affected by the fact that discretionary diversion could not be taken until 16:15 on September 20.

Table 5.2. Percentage of time the at any time dissolved oxygen standard is equaled or exceeded (i.e. attained) on the Little Calumet River (north) [LCRN] and Calumet-Sag Channel (CSAG) for WYs 2001, 2003, and 2008 applying the proposed guidelines for withdrawal of discretionary diversion at the O'Brien Lock and Dam and operation of Sidestream Elevated Pool Aeration stations 2, 3, and 4.

Location	Waterway	2001	2003	2008
Conrail Railroad	LCRN	96.82	97.03	97.80
Central & Wisconsin Railroad	LCRN	95.71	95.39	97.54
Halsted Street	LCRN	100.00	100.00	99.55
Division Street	CSAG	99.68	100.00	100.00
Kedzie Street	CSAG	100.00	99.98	100.00
Cicero Avenue	CSAG	99.92	99.92	100.00
Harlem Avenue	CSAG	100.00	99.95	100.00
Southwest Highway	CSAG	100.00	99.93	100.00
104th Avenue	CSAG	100.00	99.90	100.00
Route 83	CSAG	100.00	99.89	100.00

Table 5.3. Percentage of days the 7-day mean of the daily minimum dissolved oxygen standard is equaled or exceeded (i.e. attained) on the Little Calumet River (north) [LCRN] and Calumet-Sag Channel (CSAG) for WYs 2001, 2003, and 2008 applying the proposed guidelines for withdrawal of discretionary diversion at the O'Brien Lock and Dam and operation of Sidestream Elevated Pool Aeration stations 2, 3, and 4.

Location	Waterway	2001	2003	2008
Conrail Railroad	LCRN	100.00	96.12	95.17
Central & Wisconsin Railroad	LCRN	99.03	100.00	93.72
Halsted Street	LCRN	100.00	100.00	98.07
Division Street	CSAG	100.00	100.00	100.00
Kedzie Street	CSAG	100.00	100.00	100.00
Cicero Avenue	CSAG	100.00	100.00	100.00
Harlem Avenue	CSAG	100.00	100.00	100.00
Southwest Highway	CSAG	100.00	100.00	100.00
104th Avenue	CSAG	100.00	100.00	100.00
Route 83	CSAG	100.00	100.00	100.00

In order to achieve these results the total discretionary diversion flow withdrawn at the O'Brien L&D was 29.34, 29.84, and 93.66 cfs in WYs 2001, 2003, and 2008, respectively. Figure 5.1 shows the distribution of these discretionary diversion amounts at the O'Brien L&D throughout the year.

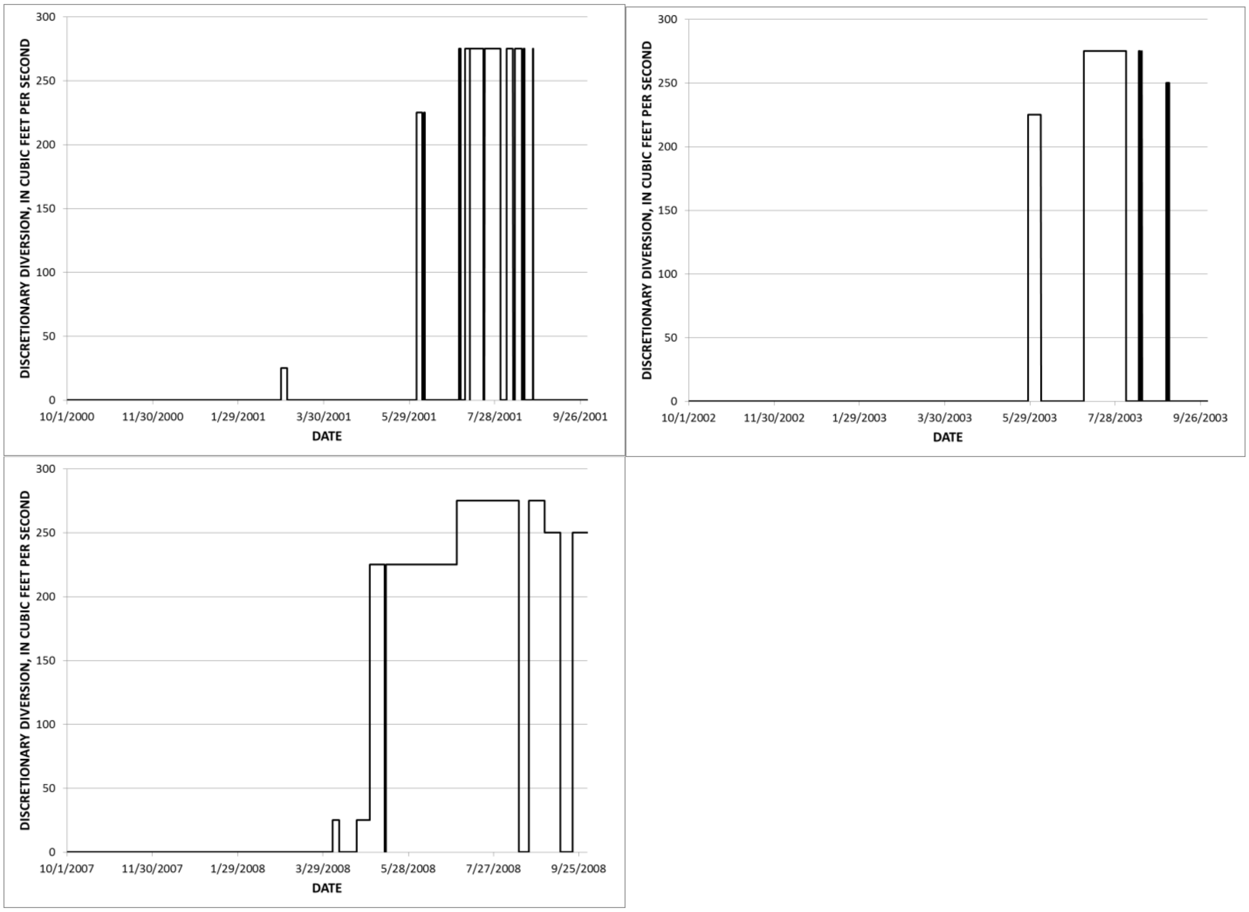

Figure 5.1. Distribution of "optimal" discretionary diversion at the O'Brien Lock & Dam for Water Years 2001, 2003, and 2008.

Table 5.4 lists the number of hours with one pump on, two pumps on, and three pumps on and the total pump hours for SEPA stations 2, 3, and 4 for WYs 2001, 2003, and 2008.

The final conclusion of these simulations is that the procedures for "optimal" withdrawal of discretionary diversion at the O'Brien L&D and operation of SEPA stations 2, 3, and 4 described in Subsections 4.3.1 and 4.3.2, respectively, result in high attainment of the DO standards with a reasonable use of discretionary diversion and the SEPA stations.

Table 5.4. Number of hours with one pump on, two pumps on, and three pumps on and total pump hours for Sidestream Elevated Pool Aeration (SEPA) stations 2, 3, and 4 for Water Years 2001, 2003, and 2008.

Year	1 Pump	2 Pumps	3 Pumps	Pump-hours
SEPA 2				
2001	5044	92		5228
2003	5132	4		5140
2008	5136	0		5136
SEPA 3				
2001	3386	249	44	4016
2003	3606	56	10	3748
2008	3660	12	0	3684
SEPA 4				
2001	3294	371	24	4108
2003	3655	36	17	3778
2008	3677	2	0	3681

5.2.3 Chicago River main stem, South Branch Chicago River, and Chicago Sanitary and Ship Canal

Table 5.5 lists the level of attainment of the at any time DO standard at various DO monitoring locations on the SBCR and CSSC for WYs 2001, 2003, and 2008 applying the procedures described in Subsections 4.4.1 and 4.4.2 with the monthly discretionary diversion flows made consistent for all years. Table 5.6 lists the level of attainment of the 7-day mean of the daily minimum DO standard at various DO monitoring locations on the SBCR and CSSC for WYs 2001, 2003, and 2008 applying the procedures described in Subsections 4.4.1 and 4.4.2 with the monthly discretionary diversion flows made consistent for all years. From Tables 5.5 and 5.6 it can be seen that the goal of 95% attainment of the DO standards is achieved at nearly all locations and years. The only exception is that the at any time DO standard is not attained 95% of the time at Loomis Street for WY 2001, however, the target is only missed by 0.03 percentage points.

Table 5.5. Percentage of time the at any time dissolved oxygen standard is equaled or exceeded (i.e. attained) on the South Branch Chicago River (SBCR) and Chicago Sanitary and Ship Canal (CSSC) for WYs 2001, 2003, and 2008 applying the proposed guidelines for withdrawal of discretionary diversion at the Chicago River Controlling Works and operation of Sidestream Elevated Pool Aeration station 5.

Location	Waterway	2001	2003	2008
Jackson Boulevard	SBCR	99.74	100.00	99.89
Loomis Street	SBCR	94.97	95.82	99.54
Cicero Avenue	CSSC	98.97	100.00	99.42
Baltimore & Ohio Railroad	CSSC	99.66	100.00	99.65
Route 83	CSSC	99.45	100.00	99.45
River Mile 302.6	CSSC	99.93	100.00	99.81
Romeoville Road	CSSC	99.65	100.00	99.74
Lockport Controlling Works	CSSC	99.55	99.93	99.72

Table 5.6. Percentage of days the 7-day mean of the daily minimum dissolved oxygen standard is equaled or exceeded (i.e. attained) on the South Branch Chicago River (SBCR) and Chicago Sanitary and Ship Canal (CSSC) for WYs 2001, 2003, and 2008 applying the proposed guidelines for withdrawal of discretionary diversion at the Chicago River Controlling Works and operation of Sidestream Elevated Pool Aeration station 5.

Location	Waterway	2001	2003	2008
Jackson Boulevard	SBCR	100.00	100.00	100.00
Loomis Street	SBCR	96.60	96.12	96.62
Cicero Avenue	CSSC	98.65	100.00	98.33
Baltimore & Ohio Railroad	CSSC	100.00	100.00	100.00
Route 83	CSSC	99.44	100.00	100.00
River Mile 302.6	CSSC	100.00	100.00	100.00
Romeoville Road	CSSC	100.00	100.00	100.00
Lockport Controlling Works	CSSC	100.00	100.00	100.00

Table 5.7 lists the levels of attainment of the various aspects of the General Use waters DO standards applicable to the Chicago River main stem at Clark Street. The increases in discretionary diversion in August and September have improved the attainment with the 30-day mean DO standard in WY 2001.

Table 5.7. Percentage of time meeting or exceeding (i.e. attaining) the various aspects of the General Use dissolved oxygen standards applicable to the Chicago River main stem at Clark Street for Water Years 2001, 2003, and 2008.

Criterion	2001	2003	2008
All times	100.00	100.00	99.87
7-day Mean	100.00	100.00	100.00
7-day Mean of Daily Minimum	100.00	100.00	100.00
30-day Mean	100.00	100.00	100.00

In order to achieve these results the total discretionary diversion flow withdrawn at the CRCW was 122.85, 142.12, and 61.85 cfs in WYs 2001, 2003, and 2008, respectively. Figure 5.2 shows the distribution of these discretionary diversion amounts at the CRCW throughout the year.

The resulting total discretionary diversion for WYs 2001, 2003, and 2008 is 204.50, 219.81, and 202.69 cfs, respectively. For WY 2008 a lot of extra water remains that may be applied to improve the attainment of the 7-day mean of the daily minimum DO standards at Simpson Street and Central & Wisconsin Railroad, particularly in September.

Table 5.8 lists the number of hours with one pump on, two pumps on, and three pumps on and the total pump hours for SEPA 5 for WYs 2001, 2003, and 2008.

Table 5.8. Number of hours with one pump on, two pumps on, and three pumps on and total pump hours for Sidestream Elevated Pool Aeration station 5 for Water Years 2001, 2003, and 2008.

Year	1 Pump	2 Pumps	3 Pumps	Pump-hours
2001	3467	175	97	4108
2003	3650	43	53	3895
2008	3629	10	36	3757

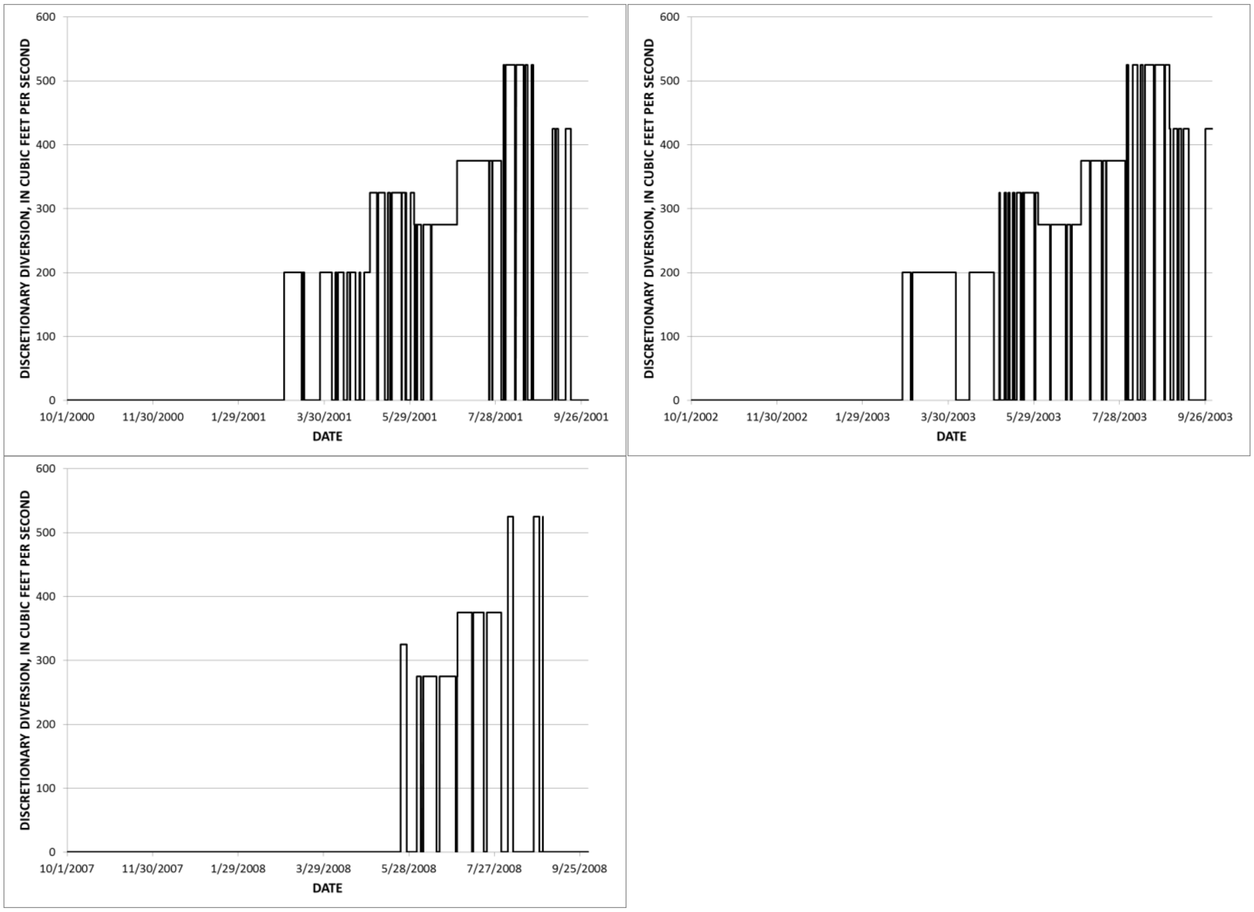

Figure 5.2. Distribution of "optimal" discretionary diversion at the Chicago River Controlling Works for Water Years 2001, 2003, and 2008.

The final conclusion of these simulations is that the procedures for "optimal" withdrawal of discretionary diversion at the CRCW and operation of SEPA 5 described in Subsections 4.4.1 and 4.4.2, respectively, result in high attainment of the DO standards with a reasonable use of discretionary diversion and the SEPA stations.

5.3 Special Conditions for September 2008

The storms of September 2008 in combination resulted in extraordinarily high CSO flows to the CAWS that would have completely filled the Thornton Reservoir and Stage 1 of the McCook

Reservoir if they had been in operation. In actual operations in 2008, the MWRDGC input large amounts of discretionary diversion to the CAWS to counteract the effects of these CSOs on water quality in the CAWS after the water levels became low enough to permit the withdrawal of discretionary diversion. In the simulations, the 7-day mean of the daily minimum DO standard could not be attained 95% of the time in WY 2008 at Simpson Street and Central & Wisconsin Railroad. A significant part of the non-attainment was in late September 2008. For WY 2008, nearly 20 cfs of discretionary diversion is still available after applying the “optimal” guidance described in Chapter 4 and earlier in this Chapter. Thus, simulations were done to determine if the 7-day mean of the daily minimum DO standard could be attained 95% of the time in WY 2008 at Simpson Street and Central & Wisconsin Railroad by utilizing higher than “optimal” discretionary diversion once discretionary diversion can be taken on September 20. For these simulations it was assumed that the withdrawal of higher discretionary diversion values would continue from 15:10 and 16:15 on September 20 at the WPS and O’Brien L&D, respectively, through the end of September.

For Simpson Street, if the discretionary diversion at the WPS was increased to 300 cfs the percentage of time meeting or exceeding the 7-day mean of the daily minimum DO standard increased to 93.24%. However, increasing the discretionary diversion at the WPS to as high as 700 cfs could not further improve the percentage of time meeting or exceeding the 7-day mean of the daily minimum DO standard. Thus, a maximum of 300 cfs was considered in the overall evaluation of DO conditions in late September 2008.

For Central & Wisconsin Railroad, if the discretionary diversion at the O'Brien L&D was increased to 600 cfs the percentage of time meeting or exceeding the 7-day mean of the daily minimum DO standard increased to 95.17%. Thus, using higher than "optimal" discretionary diversion at the O'Brien L&D could yield greater than 95% attainment of the 7-day mean of the daily minimum DO standard throughout the Calumet River system even for the extraordinary inflow conditions in September 2008. Further, using 300 cfs at the WPS and 600 cfs at the O'Brien L&D resulted in a total discretionary diversion for WY 2008 of 218.36 cfs, which is less than the allowed annual maximum of 220 cfs. Thus, for all three representative years considered in this study, all relevant DO standards can be attained greater than 95% of the time at all locations except for (A) Simpson Street, which can meet or exceed (i.e. attain) the 7-day mean of the daily minimum DO standard 93.24% of the time if the discretionary diversion at the WPS is increased to 300 cfs after 15:10 on September 20; and (B) the at any time DO standard at Loomis Street in WY 2001 (which falls short by 0.03 percentage points). Thus, it may be concluded that the guidelines developed and tested in this study have a good chance of yielding at least 95% attainment of the various DO standards throughout the CAWS while using less than the allowed amount of discretionary diversion of 220 cfs.

Chapter 6 Summary of Operational Guidance

In the following subsections the guidance for the withdrawal of discretionary diversion and the operation of the Instream Aeration Stations and Sidestream Elevated Pool Aeration stations developed and tested in this study are summarized. It should be remembered that this guidance was developed on the basis of hydraulic and water quality modeling of the Chicago Area Waterway System (CAWS) and represents "best engineering judgment" resulting from the model simulations. The performance of the guidance presented here should be continually monitored by the Metropolitan Water Reclamation District of Greater Chicago (MWRDGC), and adjustments should be made to this guidance as the MWRDGC sees fit on the basis of actual performance in attaining the DO standards for the CAWS.

6.1 Guidance for Withdrawal of Discretionary Diversion

For all locations discretionary diversion can only be withdrawn when water levels at the withdrawal points are suitable to avoid flow reversals to Lake Michigan. Otherwise the guidance for the withdrawal of discretionary diversion is given in the following subsections.

6.1.1 Wilmette Pumping Station

At the Wilmette Pumping Station continuously withdraw 100 cfs of discretionary diversion from May 15 to September 30. Outside of May 15 to September 30, if the DO concentration at DO monitors at Church Street or Main Street on the North Shore Channel falls below the at any time DO standard plus 0.3 mg/L (i.e. 3.8 mg/L for October through February and 5.3 mg/L for March 1 through May 14), 50 cfs of discretionary diversion should be withdrawn at the Wilmette

Pumping Station. This discretionary diversion should continue until the measured DO concentration at both DO monitors is greater than or equal to the at any time DO standard plus 0.3 mg/L. If the measured DO concentration at the DO monitors drops below 5.3 mg/L between February 26 and March 1, discretionary diversion should begin to avoid DO concentrations below the at any time DO standard of 5.0 mg/L starting on March 1.

6.1.2 O'Brien Lock and Dam

At the O'Brien Lock and Dam if the DO concentration at DO monitor at Conrail Railroad on the Little Calumet River (north) falls below the at any time DO standard plus 0.3 mg/L (i.e. 3.8 mg/L for August through February and 5.3 mg/L for March through July), discretionary diversion should be withdrawn at the O'Brien Lock and Dam. This discretionary diversion should continue until the measured DO concentration at the DO monitor is greater than or equal to the at any time DO standard plus 0.3 mg/L. If the measured DO concentration at the DO monitors drops below 5.3 mg/L between February 26 and March 1, discretionary diversion should begin to avoid DO concentrations below the at any time DO standard of 5.0 mg/L starting on March 1. The amount of the discretionary diversion varies by month as follows:

Month	March	April	May	June	July	August	September
Diversion (cfs)	25	25	225	225	275	275	250

If it is necessary to start discretionary diversion in February, the "optimal" amount for March should be withdrawn.

6.1.3 Chicago River Controlling Works

At the Chicago River Controlling Works discretionary diversion should only be taken in the months of March through September (with March starting on February 26 to account for the travel time from the CRCW to Loomis Street). The withdrawal of discretionary diversion should be triggered based on DO concentrations at the DO monitor at Ohio Street on the North Branch Chicago River. That is discretionary diversion begins when the measured DO concentration at Ohio Street falls below a “trigger” concentration and it ends when the DO concentration at Ohio Street exceeds this “trigger” concentration. The “trigger” concentration and the amount of discretionary diversion vary by month as indicated below.

Month	Trigger (mg/L)	Diversion (cfs)
March	7.0	200
April	6.5	200
May	6.5	325
June	6.5	275
July	6.5	375
August	5.0	525
September	5.0	425

6.2 Guidance for the Operation of the Aeration Stations

6.2.1 Devon Avenue and Webster Avenue Instream Aeration Stations

For the Devon Avenue and Webster Avenue Instream Aeration Stations the DO monitoring locations are Fullerton Avenue and Ohio Street, respectively, on the North Branch Chicago River. The operational guidance for these stations is as follows:

1) All blowers are off whenever DO concentrations at the monitoring location are at least 1.0 mg/L above the at any time DO standard (i.e. 4.5 mg/L for August to February and 6.0 mg/L for March through July).
2) Start one blower if the DO concentration drops below 1.0 mg/L above the at any time DO standard (i.e. 4.5 mg/L for August to February and 6.0 mg/L for March through

July) and leave it on until the DO concentration is greater than 1.0 mg/L above the at any time DO standard.

3) Start a second blower if the DO concentration drops below 0.7 mg/L above the at any time DO standard (i.e. 4.2 mg/L for August to February and 5.7 mg/L for March through July) and leave it on until the DO concentration is greater than 0.7 mg/L above the at any time DO standard.

6.2.2 Sidestream Elevated Pool Aeration Stations

For Sidestream Elevated Pool Aeration Station 2 (SEPA 2) the operational guidance is as follows:

1) One pump is continuously operated at SEPA 2 from April 1 to October 31.
2) If the measured DO concentration at the DO monitor at Division Street on the Calumet-Sag Channel drops below 0.3 mg/L above the at any time DO standard (i.e. less than 3.8 mg/L for August through February and less than 5.3 mg/L for March through July), a second pump should be turned on at SEPA 2, and this pump should remain on until the DO concentration exceeds 0.3 mg/L above the at any time DO standard at the DO monitor at Division Street.
3) SEPA 2 need not be operated from November 1 to March 31.

For Sidestream Elevated Pool Aeration Stations 3, 4, and 5 the DO monitors are at Cicero Avenue and 104th Avenue on the Calumet-Sag Channel and the Lockport Controlling Works on the Chicago Sanitary and Ship Canal, respectively. The operational guidance for each of these

SEPA stations is the same only based on the different DO monitoring locations. The operational guidance is as follows:

1) One pump is continuously operated at each of SEPA 3, SEPA 4, and SEPA5 from May 1 to September 30.
2) For May 1 to September 30, if the DO concentration at the DO monitoring location drops below 0.6 mg/L above the at any time DO standard (i.e. less than 4.1 mg/L for August through February and less than 5.6 mg/L for March through July), a second pump should be turned on at the SEPA station, and this pump should remain on until the DO concentration exceeds 0.6 mg/L above the at any time DO standard at the DO monitoring location.
3) For the May 1 to September 30, if the DO concentration at the DO monitoring location drops below 0.3 mg/L above the DO standard (i.e. less than 3.8 mg/L for August through February and less than 5.3 mg/L for March through July), a third pump should be turned on at the SEPA station, and this pump should remain on until the DO concentration exceeds 0.3 mg/L above the at any time DO standard at the DO monitoring location.
4) For October 1 to 31 and April 1 to 30, if the DO concentration at the DO monitoring location drops below 0.9 mg/L above the at any time DO standard (i.e. less than 4.4 mg/L for October and less than 5.9 mg/L for April), one pump should be turned on at the SEPA station, and this pump should remain on until the DO concentration exceeds 0.9 mg/L above the at any time DO standard at the DO monitoring location.
5) For October 1 to 31 and April 1 to 30, if the DO concentration at the DO monitoring location drops below 0.6 mg/L above the at any time DO standard (i.e. less than 4.1 mg/L for October and less than 5.6 mg/L for April), a second pump should be turned on at the

SEPA station, and this pump should remain on until the DO concentration exceeds 0.6 mg/L above the at any time DO standard at the DO monitoring location.

6) For the October 1 to 31 and April 1 to 30, if the DO concentration at the DO monitoring location drops below 0.3 mg/L above the at any time DO standard (i.e. less than 3.8 mg/L for October and less than 5.3 mg/L for April), a third pump should be turned on at the SEPA station, and this pump should remain on until the DO concentration exceeds 0.3 mg/L above the at any time DO standard at the DO monitoring location.
7) SEPA 3, 4, and 5 need not be operated from November 1 to March 31.

It should be noted that in this study rules 4-6 were only needed for short periods in October 2000 for SEPA 3, October 2002 and 2007 for SEPA 4, and October in all three years for SEPA 5, but it is possible that such conditions could occur in other years for actual operations in April and the need for SEPA operations under such conditions should be prepared for.

In the simulations, there was no need to operate SEPA 2, 4, and 5 during the period of November to March. SEPA 3 also did not need to be operated during the period of November to April [except for 14 hours in March 2001]. However, this does not mean that in other years, such operations would not be necessary. The measured DO data on the Calumet-Sag Channel was reviewed to determine if DO concentrations less than the at any time DO standard occurred in November to March. The results are listed in Table 6.1.

Table 6.1 Number of measured dissolved oxygen (DO) concentrations less than the at any time DO standard on the Calumet-Sag Channel.

Month	Hours < DO standard	Total hours	Data period
Division Street			
November	0	2222	July 2001 – March 2004
December	0	2232	
January	0	2232	
February	0	2040	
March	0	2051	
Kedzie Street			
November	0	2051	July 2001 – March 2004
December	0	2120	
January	0	1690	
February	0	2039	
March	0	2051	
Cicero Avenue			
November	15	9042	July 2001 – May 2017
December	0	9349	
January	0	8922	
February	0	8134	
March	14	9303	
Harlem Avenue			
November	0	2833	July 2001 – March 2004
December	0	2064	
January	0	2231	
February	0	2040	
March	0	2051	
Southwest Highway			
November	0	2722	July 2001 – March 2004
December	0	2232	
January	0	1547	
February	0	1908	
March	0	2050	
104th Avenue			
November	268	5036	July 2001 – May 2010
December	535	4105	
January	0	4755	
February	1	4210	
March	0	4423	
Route 83			
November	14	12814	August 1998 – May 2017
December	0	13195	
January	0	12226	
February	0	11212	
March	44	12526	

With the exception of the measured DO concentrations at 104th Avenue, DO concentrations less than the at any time DO standard are very rare throughout the Calumet-Sag Channel. Further, the low measured DO concentrations at 104th Avenue appear to be questionable because they are substantially lower than the measured DO concentrations 3.2 miles downstream at Route 83. Thus, the traditional shut down of the SEPA stations from November to March is reasonable from environmental as well as practical operational considerations.

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