UPPER MISSISSIPPI RIVER BASIN

ILLINOIS WATERWAY – NINE FOOT CHANNEL

APPENDIX 1

MASTER WATER CONTROL MANUAL

T.J. O'BRIEN LOCK & CONTROLLING WORKS

DEPARTMENT OF THE ARMY
CHICAGO DISTRICT, CORPS OF ENGINEERS
CHICAGO, ILLINOIS

NOTICE TO USERS OF MANUAL

Regulations specify that this Water Control Manual be published in a hard copy binder with loose-leaf form, and only those sections or parts thereof requiring changes will be revised and printed. Preserve this copy in good condition so that inserts can be made to keep the manual current. Changes to individual pages must carry the date of revision, which is the Division's approval date.

EMERGENCY REGULATION ASSISTANCE PROCEDURES

In the event that unusual conditions arise during non-duty hours, communication can be achieved by contacting, in the order listed, one of the following personnel by phone or the District VHF-FM radio:

Name/Title	Duty Hour Phone
MWRD Systems Dispatcher	[redacted]
Lock Facility	[redacted]

WATER CONTROL MANUAL

O'BRIEN LOCK & CONTROLLING WORKS UPPER MISSISSISSIPPI RIVER BASIN

ILLINOIS WATERWAY, NINE-FOOT CHANNEL
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MAY 2024

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(See Exhibit A for additional information)

Thomas J. O'Brien Lock and Controlling Works

Location	Calumet River River Mile 326.0
Lock Dimensions	110 feet wide by 1,000 feet long
Maximum Lift	5.0 feet

Conversion from NGVD (1929) Datum to NAVD 1988 Datum by Project

T.J. O'Brien Lock	0.00 feet NGVD = -0.34 feet NAVD 88

INTRODUCTION

1-01. Authorization. This reservoir regulation manual has been prepared in accordance with directives contained in:

a. ER 1110-2-240, Engineering and Design, Water Control Management, 30 May 2016.
b. EM 1110-2-3600, Management of Water Control Systems, 10 Oct 2017.
c. ER 1110-2-8156, Preparation of Water Control Manuals, 30 Sep 2018.
d. DIVR 1110-2-240, Water Control Management, Preparation of Water Control Manual Plans and Manuals, 1 Jan 1992.

1-02. Purpose and Scope. The purpose of this water control manual is to present the detailed plan of water control and pertinent information relative to T.J. O'Brien Lock and Controlling Works. This manual presents a description and history of the project, watershed characteristics, data collection and communication networks, hydrologic forecasts, the Water Control Plan, the effect of the Water Control Plan, and water control management of the project. The T.J. O'Brien Lock and Controlling Works is located on the Calumet River upstream of Lockport Lock and Dam. Additional facilities along the canal system include the Lockport Controlling Works, Willow Springs Spillway, Wilmette Pumping Station, and the Chicago River Lock and Controlling Works.

1-03. Related Manuals and Reports. This manual is an appendix to the "Master Water Control Manual, Upper Mississippi River Basin, Illinois Waterway, Nine-Foot Channel, Aug 1996." A similar appendix for each Lock and Dam within the Chicago District has been prepared. The Emergency Action Plan for the T.J. O'Brien Lock and Controlling Works is currently being updated as of this revision to the water control manual.

1-04. Project Owner. The Metropolitan Water Reclamation District (MWRD) is the owner of the Lockport Powerhouse, Lockport Controlling Works, Chicago River Controlling Works (CRCW), and the Wilmette Pumping Station (WPS). The United States Government is the owner of the T.J. O'Brien Lock and Controlling Works, Lockport Lock, and Chicago Harbor Lock. Table 1-1 contains a list of facilities described in this report and the appropriate owner, operating, and regulating agency.

1-05. Operating Agency. Within the Chicago Area Waterway System (CAWS), the Corps of Engineers, Chicago District (LRC) is responsible for the operation and maintenance of the T.J. Obrien Lock and Controlling Works. The Corps of Engineers, Chicago District is responsible for the operation and maintenance of the Chicago Lock. In addition, the Corps of Engineers is responsible for maintaining impoundment structures along the waterway. The Lockmaster and personnel at T.J. O'Brien Lock and Control Works receive operating instructions from MWRD in regard to water control operations. MWRD is responsible for the operation of the Lockport Powerhouse and Controlling Works, the CRCW, and the WPS.

Table 1-1 Owners, Operating Agencies, and Regulating Agencies for the Facilities of the Waterway System

1. Lockport Lock	USACE	USACE[e]	USACE[e]
2. Lockport Powerhouse	MWRD	MWRD[b]	MWRD, FERC
3. MWRD Lock at Lockport	MWRD	------[a]	------[a]
4. Lockport Controlling Works	MWRD	MWRD[d]	MWRD
5. Chicago Harbor Lock	USACE	USACE[c, e]	USACE[e], MWRD
6. Chicago River Controlling Works	MWRD	MWRD	MWRD
7. T.J. O'Brien Lock and Controlling Works	USACE	USACE[e]	USACE[e], MWRD
8. Wilmette Pumping Station	MWRD	MWRD	MWRD

Note: USACE = U.S. Army Corps of Engineers
MWRD = Metropolitan Water Reclamation District
FERC = Federal Energy Regulatory Commission

[a] The MWRD Lock at Lockport was taken out of service in 1946.
[b] The USACE has the responsibility to maintain the foundation and dam portion of the Powerhouse.
[c] Prior to October 1, 1984 operated and maintained by MWRD.
[d] The USACE has no ownership, however, it has the responsibility to maintain the foundation, piers, dolphins, and all the concrete at the Lockport Controlling Works and the gravity structure of the dam at Lockport as well as the canal walls in between.
[e] Chicago District is the responsible USACE agency.

1-06. Regulating Agency. USACE regulates the Lockport Lock while the regulation of the Chicago Lock and T.J. O’Brien Lock and Control Works is coordinated by MWRD with USACE. Beginning in Water Year 1987, the Corps of Engineers, Chicago District is the lead agency for monitoring and computing the diversion of water from Lake Michigan at Chicago, Illinois.

The MWRD is responsible for the collection, treatment, and disposal of wastewater, providing for flood control, and the operation of the CAWS in coordination with USACE. The MWRD maintains a network of meteorological and hydrologic monitor stations that provide information on current and anticipated storm conditions and levels of Lake Michigan and the CAWS. These data and forecast techniques are used to operate the CAWS on a real-time basis.

1-07. Vertical Datum. The T.J. O’Brien Lock and Controlling operations continue to use CCD as its vertical datum while its infrastructure uses NAVD88 as their vertical datum.

DESCRIPTION OF PROJECT

2-01. General. The Illinois Waterway (IWW) provides a 9-foot navigation channel, 327.0 miles in length, between Lake Michigan at Chicago, Illinois and the Mississippi River at Grafton, Illinois. There are nine Locks and Dams along the IWW which lower navigation traffic a total of 140 feet over eight lock steps, with the largest drop being 39 feet at Lockport Lock and Dam. The Chicago Harbor Lock (CHL) and Chicago River Controlling Works (CRCW) form the upstream end of the Chicago Area Waterway System (CAWS). The Chicago and Thomas J. O'Brien Locks, located near the mouth of the Chicago River and Calumet River, respectively, provide a navigation connection between Lake Michigan and the CAWS. The Chicago River and Calumet River join at the Calumet-Sag Junction, 12.3 miles upstream of Lockport Lock and Dam, on the Chicago Sanitary and Ship Canal (CSSC). The locks on the IWW from upstream to downstream are the Thomas J. O'Brien Lock and CHL at Lake Michigan, Lockport Lock, Brandon Road Lock, Dresden Island Lock, Marseilles Lock, Starved Rock Lock, Peoria Lock, and LaGrange Lock.

2-02. Location. The T.J. O'Brien Lock, which is operated and maintained by Chicago District, U.S. Army Corps of Engineers, provides navigation services between Lake Michigan at Calumet Harbor and the Illinois Waterway downstream of Lockport Lock and Dam. The general location of the T.J. O'Brien Lock along with the associated watershed is shown on Plate 2-1. The T.J. O'Brien Lock and Controlling Works are located at River Mile (RM) 326.0, approximately 35 miles upstream of Lockport Lock and Dam, on the Calumet River and connect to the Chicago Sanitary and Ship Canal via the Calumet-Sag Channel. The T.J. O'Brien Lock and Controlling Works are located in the southeastern portion of Chicago, Illinois. A plan view of the project is shown on Plate 2-2.

2-03. Purpose. The purpose of the T.J. O'Brien Lock and Controlling Works is to control the direct diversion, the flow of water movement of water between Lake Michigan and the Calumet River, while maintaining navigation. The direct diversion consists of four components: lockage, leakage, discretionary flow, and navigation makeup flow. The lockage component is the flow used in locking vessels to and from the lake and, during the winter, flushing ice from the lock chamber. The leakage component is water estimated to pass, in an uncontrolled way, through or around the lakefront structures. The purpose of the discretionary diversion is to improve water quality in the canal system. Navigation makeup water is composed of two parts. When large storms are forecast, the canal is drawn down before the storm to prevent flooding, and navigation makeup water is used during this draw down period to maintain navigation depths. If the runoff is not enough to refill the canal, additional navigation makeup water is allowed to pass from Lake Michigan to return the canal system to its normal operating stage.

2-04. Physical Components. The Cal-Sag Channel, which was completed in 1922, connects the Calumet watershed to the CSSC. This man-made waterway also converts a sizeable amount of the Great Lakes Basin to the Upper Mississippi River Basin. The

Cal-Sag Channel was enlarged in 1960. In 1965 the O’Brien Lock and Dam was built on the Calumet River to replace the Blue Island Lock on the Little Calumet River. The O’Brien Lock and Dam consists of a low-lift lock and four sluice gates. To reduce the risk of invasive carp entering Lake Michigan a metal screen has been installed on one sluice gate for diversion. During severe rainstorm events, opening all sluice gates and the lock to reverse floodwaters to Lake Michigan is often needed to prevent flooding in southern Chicago areas.

a. T.J. O’Brien Lock. The walls of T.J. O’Brien Lock consist of a series of bonded rock filled cells contained by sheet piling. The lock has a clear length of 1,000 feet and a width of 110 feet, with a maximum lift of 5 feet. The upstream and downstream ends of the chamber are each sealed by a set of framed steel sector gates. The sector gates are 22.75 feet high with a bottom sill of -17.0 feet CCD and are comprised of two leaves. The radius of each gate leaf is 60.92 feet. The sector gates are operated by a gate mounted rack with a wall mounted bull gear drive using an electric motor-driven hydraulic transmission system. The gate bay monoliths consist of reinforced concrete and are shaped to form recesses for the sector gates.

The filling of the lock chamber is by gravity flow through culverts within the land and river walls or through incremental opening of the upper sector gates. The lock is normally filled and emptied by opening the sector gates. Alternatively, a culvert 10 feet high by 10 feet wide along a hydraulically driven sluice gate valve are contained within the upper gate blocks of the land and river walls to control the filling of lock chamber. Emptying of the lock is through the incremental opening of the downstream sector gates only. A plan view of the lock with cross-section details is shown on Plate 2-2 and 2-3. The upper and lower guide walls are comprised of tied- back steel sheet pile structures. The upper guide wall extends 1,000 feet upstream at +7.0 feet CCD. The lower guide wall extends 1,000 feet downstream at +5.0 feet CCD.

b. T.J. O'Brien Dam and Controlling Works. The dam has a total length of 257 feet and is tied into the river wall on the west side and extends easterly to the left bank. The dam consists of a fixed section approximately 204 feet long and a controlling works segment, approximately 53 feet long. The fixed segment consists of steel sheet pile cellular construction founded on soil with two cells between the river wall and the control structure and 6 cells connecting to the left bank. The control structure is of reinforced concrete construction founded on steel H-piles and contains four slide gates. Each gate is 10 feet wide by 10 feet high with the gate sill at -13.0 feet CCD and is equipped with hoisting machinery driven by an electric motor, and a hand crank for emergency operation. A plan view of the controlling works is shown on Plate 2-4.

2-05. Related Control Facilities. The related control facilities include the east and west bank channel walls, the WPS, the Chicago Harbor Lock, the CRCW, the Lockport Powerhouse, Lockport Controlling Works, the Lockport Lock, the Thomas J. O’Brien

Lock and Controlling Works, and the Tunnel and Reservoir Plan (TARP). All the related control facilities are operated by the MWRD with the exception of the Chicago Harbor Lock, Thomas J. O'Brien Lock and Controlling Works and the Lockport Locks which are operated by the Chicago District, Corps of Engineers.

Water entering the Lockport Pool directly from Lake Michigan is regulated by three lakefront structures. The Wilmette Pumping Station (WPS) regulates the flow of water from Lake Michigan to the North Shore Channel, the CHL and CRCW regulates the flow from Lake Michigan to the Chicago River, and the Thomas J. O'Brien Lock and Controlling Works regulates the flow of water from Lake Michigan to the Calumet River. In addition, water is pumped from Lake Michigan for domestic purposes and enters the waterway as the effluent from water reclamation plants.

Three intermediate facilities are located between the upstream structures along Lake Michigan and the downstream lock and dam at Lockport. These facilities include the east and west bank channel retaining walls, the Lockport Controlling Works, and the Willow Springs Spillway. The Willow Springs Spillway was purposely blocked with rubble in 1955 and is currently inoperable

a. <u>East and West Bank Channel Walls</u>. The east and west embankments are located immediately upstream of the Lockport Lock and Dam. The left or east embankment extends upstream from the lock approximately one mile. The embankment is 50 feet wide on top with a canal wall standing nearly vertical. The canal wall is constructed of rock excavated from the canal. The canal wall along the east bank was rehabilitated in 2015 as a part of ongoing major rehabilitation project. A typical cross-section of the rehabilitated river wall is shown on Plate 2-5. The right or west embankment extends upstream from the Lockport Powerhouse approximately 1.9 miles. The wall is constructed of earth and rock and has a concrete core wall that extends 4,300 feet upstream of the powerhouse. A new concrete cutoff wall was completed in 2009 as Stage I of the ongoing major rehabilitation project. The top of the embankment is 33 feet wide in the concrete core section and 50 feet wide in the earth and rock section upstream. A new roller compacted concrete was completed in 2017.

b. <u>Wilmette Pumping Station</u>. The Wilmette Pumping Station is located on the North Shore Channel, approximately 1,500 feet from the open waters of Lake Michigan. The pump house forms a part of the structure of the Sheridan Road Bridge over the North Shore Channel in Wilmette, Illinois. The location of the WPS is shown on Plate 2-1, while its principal features are shown on Plate 2-6. The purpose of the WPS is to control the diversion of water from Lake Michigan to the North Shore Channel. The pumping station is also used for flood control and waterway flushing and functions as a component of the diversion control system. The configuration of facility after the 2013 completion of a recent rehabilitation consists of three sluice gates, two pumps (one 150-cfs variable speed pump for use as primary diversion and a 250-cfs pump for back-up), and two tunnels.

c. <u>Lockport Lock and Dam</u>. The Lockport Lock is a gravity wall design 110 feet wide by 600 feet long. The maximum lift is 42.0 feet, and the average lift is 38 feet. The upstream end has two vertical lift gates whereas the downstream end has conventional gates.

The Lockport Dam consists of the abandoned MWRD Lock and the Lockport Powerhouse and associated Controlling Works which are operated by MWRD. This structure along with the Lockport Lock makes up the downstream impounding structure of the Lockport Pool. The MWRD Lock is adjacent to the Lockport Lock and was taken out of operation in 1946. The upstream end of the lock has subsequently been sealed with a concrete bulkhead.

d. Lockport Controlling Works. The Lockport Controlling Works is located on the CSSC at River Mile 293.2. The site is located 2.2 miles upstream of the Lockport Lock and Powerhouse, and one-half mile northwest of Lockport, Illinois. The location of the Lockport Controlling Works is shown on Plate 2-1. The Lockport Controlling Works consists of a dam 260 feet in length which contains 15 gate openings. Eight of the gate openings have never been used and are now bulkheaded. The remaining seven gate openings are each equipped with a vertical lift sluice gate. A plan view of the Controlling Works is shown on Plate 2-7. During major rainfall events, the Lockport Controlling Works are operated to maintain maximum and minimum pool elevations on the CSSC for navigation when the capacity of the Lockport Powerhouse is exceeded.

e. 95th Street Pumping Station. The 95th Street Pumping Station is an interceptor lift station located along the Calumet River near Turning Basin #1, as shown in Plate 2-8. The station was constructed in 1924 and has six pumps that provide a maximum backflow capacity of 856 cfs.

f. 122nd Street Pumping Station. The 122nd Street Pumping Station is an interceptor lift station located along the Calumet River northeast of Wolf Lake, as shown in Plate 2-9. The station was constructed in 1963 and has seven pumps that provide a maximum backflow capacity of 391 cfs.

g. Tunnel and Reservoir Project. The Tunnel and Reservoir Plan (TARP) was adopted by the MWRD in 1972 to address the combined sewer overflow (CSO) pollution and flooding problems in the Chicago-land area served by combined sewers. The project is made up of four separate tunnel systems which are the Mainstream, Des Plaines, Calumet, and O'Hare systems, along with three reservoirs as shown on Plate 2-10. TARP, when finished, will provide a total storage volume of 17.5 billion gallons (BG) (53,705 acre-feet). The system is designed to collect and store excess storm water and raw sewage which previously discharged into the canal when the Water Reclamation Plants (WRPs) capacity was exceeded. As capacity becomes available at the WRPs, the stored water is treated before being released into the canal. The tunnel portion of the project, which began in 1985 and was completed in 2006 as part of Phase I, consists of 109.4 miles of deep, large diameter, rock tunnels provide 2.3 BG (7,058 acre-feet) of storage. The tunnels range from 9 to 33 feet in diameter and are located 200 to 350 feet below ground. Sections of the tunnel system were put into operation upon completion throughout

Phase I.

Phase II of TARP consists of three reservoirs intended primarily for flood control and will also enhance pollution control benefits being provided under Phase I. The O'Hare Reservoir, completed in 1998 by the Corps of Engineers, Chicago District, is connected to the O'Hare system and provides 350 million gallons (MG) (1074 acre-feet) of storage. The Thornton Reservoir, which is part of the Calumet System, is being constructed in two stages. The first stage, a temporary 3.1 BG (9,514 acre-feet) Natural Resources Conservation Service (NRCS) reservoir called the Thornton Transitional Reservoir, was completed in March 2003 in the West Lobe of the Thornton Quarry. The second stage is a permanent 7.9 BG (24,244 acre-feet) combined NRCS/CUP reservoir, called the Thornton Composite Reservoir, to be located in the North Lobe of the Thornton Quarry. The Thornton Composite Reservoir was completed in 2015. The Thorn Creek Overflow Tunnel was connected to the Thornton Composite Reservoir and the Thornton Transitional Reservoir was decommissioned in September 2022. The McCook Reservoir, located at the downstream end of the Mainstream and Des Plaines Systems, is to be completed in two phases. Phase 1 of McCook Reservoir is completed and provides a storage capacity of 3.5 BG. Phase 2 is scheduled to be completed in 2029, increasing the total storage capacity of the reservoir to 10 BG (30,689 acre-feet).

2-06. Real Estate Acquisition. USACE owns approximately 1 mile along the waterway's west bank, with varying width, primarily 200+ feet wide along the locks' structure. The west area totals over 25 acres. Along the east area, USACE owns approximately 4.4 acres within the river and land, allowing for the water level control structures abutment and access. Much of the lock and dam was constructed under navigational servitude. The east and west areas are illustrated in Plate 2-11.

2-07. Public Facilities. A list of public facilities located along the CSSC, and its related drainage ways and watersheds is given in Table 2-1(Refer to page T2-1). Although there are several public boat ramps along Lake Michigan only three are active within CAWS 1) Richard J. Daley Boat Launch on the Chicago Sanitary and Ship Canal, 2) Work Boat Launch on the Calumet Sag Channel, 3) Alsip Boat Launch on the Calumet Sag Channel.

HISTORY OF PROJECT

3-01. Authorization for Project. The Illinois Waterway stretches approximately 327 miles across the state of Illinois from Lake Michigan at Chicago, Illinois to the Mississippi River at Grafton, Illinois. There are eight lock steps along the waterway and nine lock structures with two structures at Lake Michigan on the Chicago River and the Calumet River. Navigation traffic from Lake Michigan is lowered a total of 140 feet to the Mississippi River with the largest drop being 39 feet at Lockport Lock and Dam. The lock system with associated dams allows a minimum 9-foot channel depth for the full length of the waterway. Exhibit B is a memorandum summarizing the history of the variety of authorities that govern the activities of the Corps with respect to the CAWS.

Initial use of the waterway as a transportation route began with the Native Americans and early white explorers and trappers. At that time, a portage across a low ridge dividing the Chicago River and the Des Plaines River basins was necessary. Use of the Chicago River and Des Plaines River as a transportation route continued to increase through 1816 when an agreement was reached between the United States and local Native Americans that transferred ownership of a parcel of land containing the low-level divide between the Chicago River and the Des Plaines River to the Illinois Territory in exchange for a small sum of money and a commitment to develop a waterway transportation route between the two rivers. The agreement reserved a 20-mile-wide strip of land extending from the mouth of the Chicago River to the confluence of the Kankakee River and Des Plaines River, and a 10-mile-wide strip of land continuing along the Illinois River to the confluence of the Fox River with the Illinois River.

a. Illinois-Michigan Canal. In 1827 Congress passed the first of many acts which resulted in the construction of the Illinois-Michigan (I&M) Canal, providing an 18-foot-wide navigation link between Lake Michigan and the Illinois River at LaSalle, Illinois. The I&M Canal was constructed by the state of Illinois from 1836 to 1848. The canal is located generally along the same route as the present Chicago Sanitary and Ship Canal (CSSC) and the Des Plaines River, from the village of Summit, Illinois, located 2.5 miles west of the Chicago Midway International Airport, to LaSalle, Illinois.

b. Chicago Sanitary and Ship Canal. Beginning in the 1850's, the City of Chicago began building a comprehensive combined sewer system which was then state of the art at that time which dumped into the Chicago River System which emptied into Lake Michigan. Due to the extremely flat topography the developing city had to be raised 10 to 15 feet to allow the sewers to drain by gravity to the river. The plan called for diluting and flushing the system with water diverted from Lake Michigan. As the City grew and the combined sewer system expanded, the Chicago River became increasingly polluted, especially the South Branch of the Chicago River were much of the city's industry was located. Concerned with the adverse health effects associated with polluted water entering Lake Michigan, Chicago's water supply source, the City began utilizing the I&M canal as an effective means of passing polluted waters into the Des Plaines River, away from Lake Michigan. Consequently, the I&M Canal was deepened in the late 1860's to increase its sewage handling capabilities, and additional pumps were installed at the Bridgeport

Pumping Station which pumped water from the Chicago River into the I&M Canal away from Lake Michigan. These enlarged facilities, completed in 1871, reversed the Chicago River's flow direction as the pumps pulled Lake Michigan water through the Chicago River and the I&M Canal. However, with Chicago's continued growth, this system could not maintain the reversal especially during major rainfall events. Consequently, the Chicago River and therefore Lake Michigan were becoming increasingly polluted.

On August 2, 1885, the Chicago area received around 5.5 inches of rainfall in less than 24 hours quickly overwhelming the sewage system and discharging large amounts of polluted water into Lake Michigan. Fortunately, sustained high winds out of the northeast kept the sewage from reaching the city's water intakes located two miles offshore preventing what could have been a major epidemic. In 1887, the Drainage and Water Supply Commission recommended a major plan for collecting and disposing of Chicago's sewage and, in 1888, the Sanitary District Act was ratified by referendum of the people. Subsequently, the Illinois General Assembly authorized the establishment of the Sanitary District of Chicago – now called the Metropolitan Water Reclamation District of Greater Chicago (MWRD) -- in 1889 to implement the construction of the Chicago Sanitary and Ship Canal to divert contaminated storm and sanitary wastewaters out of the Lake Michigan basin.

In 1892 the Sanitary District began construction of the Chicago Sanitary and Ship Canal. The canal was constructed with the secondary purpose of providing an expanded replacement for the Illinois-Michigan Canal. The CSSC was completed in 1900, extending from Lake Michigan at Chicago to the Lockport Controlling Works. Completion of the toll-free CSSC marked an end to the use of the I&M Canal. Reduced traffic and revenues, maintenance problems, and limited lock dimensions were significant factors that contributed to the abandonment of the canal.

In September of 1907, the Sanitary District began construction of the North Shore Channel in order to expedite the movement of sewage from the north end of the Sanitary District including the North Branch of the Chicago River by diverting water from Lake Michigan. The channel extends from Lake Michigan at Wilmette, Illinois to the North Branch of the Chicago River. The diverted water would then flow through the South Branch of the Chicago River, the Chicago Sanitary and Ship Canal, and then into the Illinois Waterway through a controlling structure at Lockport, Illinois. The North Shore Channel was completed in November of 1910 with the Wilmette Pumping Station being the controlling structure for lake diversion. The Chicago River channel was enlarged in 1912 to increase channel conveyance. Following completion of the North Shore Channel, the Sanitary District began work on the Calumet-Sag Channel. The purpose of the Calumet-Sag Channel was to reverse the natural flow of water in the Calumet and Little Calumet Rivers away from Lake Michigan to the Mississippi River watershed by providing a connection to the Chicago Sanitary and Ship Canal. This would allow waters from the Calumet River, which were polluted by sanitary sewer overflows, to be directed away from Lake Michigan. A secondary purpose was to provide a navigation facility for industrial development along the Calumet and Little Calumet Rivers. Construction began on September 18, 1911 and was completed on August 25, 1922. The original controlling structure for the Calumet- Sag Channel was located near the terminus of the channel at Blue Island. The Blue Island Lock and Controlling Works were abandoned and partially removed in 1965 following construction of the Thomas J. O'Brien Lock and Controlling Works which were completed in 1959 by the Corps.

Early in the 1920's the Sanitary District began constructing an extensive system of intercepting sewers and sewage treatment works (now called water reclamation plants) due to political pressure regarding the diversion of water out of Lake Michigan to flush the canal. The Calumet Sewage Treatment Works (now called the Calumet Water Reclamation Plant) and the North Side Sewage Treatment Works (now called the O'Brien Water Reclamation Plant) were completed in 1922 and 1928 respectively. A suit against the Sanitary District was resolved by the U.S. Supreme Court in 1930 and resulted in a reduction of the amount of water being diverted from Lake Michigan. The order in effect changed the Sanitary District's priorities to wastewater treatment during the initial collection of polluted water and the dilution of untreated effluent. Ultimately the decree led to the construction of the West Side Sewage Treatment Works (1931), and the Southwest Sewage Treatment Works (1939) (both now called the Stickney Water Reclamation Plant).

Meanwhile, the State of Illinois approved a $20 million bond issue in 1908 providing for the channelization of the Des Plaines River and the Illinois River from Lockport to Utica, Illinois. In 1920 the State of Illinois began work on the development of the Illinois Waterway which included the Chicago Sanitary and Ship Canal and expanding locking facilities at Lockport and four other locations along the Des Plaines and Illinois Rivers. The expanded lock and channel dimensions were designed to be compatible with the current Mississippi River system requiring a nine-foot channel and 110-foot-wide locks. The project was approximately 75% complete in 1930 when, due to financial difficulties, the State of Illinois turned the project over to the Federal Government. The Federal Government, by authority of the Rivers & Harbors Act of July 3, 1930, No. 126/71/2, assumed responsibility for the unfinished state project. The project was completed in 1933. The Illinois Waterway was further improved during the mid-1930s by the construction of Peoria Lock and Dam and La Grange Lock and Dam to replace four outmoded facilities between Utica and Grafton, Illinois.

c. Tunnel and Reservoir Plan (TARP). Despite the reversal of the Chicago River, sewage and contaminants continued to accumulate in the rivers, canals, and Lake Michigan. The persistence of the problem was due mainly to the fact that Chicago and many of the older suburbs were served by combined sewers, in which both sanitary and storm sewer flow are conveyed together through the same conduits. Furthermore, continued development over the years has resulted in increased amounts of runoff entering the sewer system. During rainfall events, the sewer system and treatment plants often could not accommodate the additional flow, and combined sewage would overflow to the local waterways over 100 days per year. Within the combined sewer areas there were over 600 outfalls that released combined sewer overflow into the waterways. During particularly large storms, the rivers were forced to reverse to their natural direction to relieve flooding in the Chicago area, releasing raw sewage into the lake through the lakefront control structures. Beach closings were frequent along the Lake Michigan shoreline and the area's waterways were polluted and mostly devoid of aquatic life. In addition, combined sewage would back up into the basements of homes and businesses.

Severe flooding in 1954 and again in 1957 compelled MWRD and other agencies to study what could be done to improve the system's ability to better handle extreme events in regard to capacity and the discharging of combined sewage and storm water into the canals and ultimately into Lake Michigan. Studies in the late 1960s ultimately led to the recommendation of the TARP. In 1972, Congress, in amendments to the Water Pollution Control Act (Clean Water Act), required that water pollution from all sources in urban-industrial areas be controlled. The District adopted TARP in 1972 as the Chicago area's plan to cost-effectively comply with Federal and State water quality standards in the 375 square mile combined sewer area consisting of the City of Chicago and 51 suburbs.

TARP's main goals are to protect Lake Michigan, the region's drinking water supply, from raw sewage pollution, improve water quality of area's rivers and streams, and provide an outlet, augmented with temporary off-channel storage, for floodwaters, and to reduce street and basement sewage backup flooding. TARP consists of the Deep Tunnel System, coupled with reservoirs, drop shafts, connecting structures, pumping stations, and other appurtenances for the capture and storage of combined sewer overflows and for conveying the stored combined sewer overflows to WRPs for treatment. A more detailed description of TARP is found in section 3-03 b.

d. Stormwater Management Initiatives. Public Act 93-1049 (Chapter 70 of the Illinois Compiled Statues, Section 2605/7h), which granted MWRD stormwater management authority for Cook County, was passed in 2004 recognizing the need to take a system-wide approach in dealing with stormwater management issues at the local level. MWRD adopted the Cook County Stormwater Management Plan (CCSMP) in 2007 laying out the mission, goals, and program elements to be followed. Detailed Watershed Plans (DWPs) were completed in 2010 for the six designated watersheds including the Calumet-Sag Channel, Upper Salt Creek, Little Calumet River, Poplar Creek, North Branch of the Chicago River, and Lower Des Plaines River.

The DWP provides a summary of the watershed's stormwater management areas of concern that have been identified and need further analysis. The typical areas of concern involve eroding streambanks and placement structures, infrastructure, and/or public safety at risk and overbank flooding of regional waterways, and inadequate local storm sewer systems. The stormwater management Capital Improvement Program (CIP) consists of DWP projects approved for preliminary engineering by the Board of Commissioners. In addition to a detailed review of DWP assumptions and determination of the project's viability, preliminary engineering includes evaluation of right-of-way requirements, state and federal government permit compliance, and analysis of potential stormwater management technologies. A Watershed Management Ordinance (WMO) was developed to establish uniform stormwater management regulations for development and redevelopment projects in Cook County. The WMO went into effect on May 1, 2014. On May 7, 2020 it was amended. Components that may be regulated under the WMO include drainage and detention, floodplain management, wetland and riparian area protection, soil erosion and sediment control, and water quality.

In addition, MWRD has implemented programs to address excessive infiltration and inflow into local sanitary sewer systems. There are 125 locally owned and operated sanitary sewer systems within MWRD's eight service basins that are in the sanitary sewer rehabilitation program. These local systems are tributary to MWRD's system of large diameter interceptor (trunk) sewers and receiving water reclamation plants. In addition to capital improvements and the provision of temporary storage, the rehabilitation program requires each system to develop and implement a long-term operation and maintenance program.

Prior to the late 1930s, combined sewer systems were developed within the Chicago area which conveyed sanitary wastewater and storm water together within the same network. The capacity of the treatment plants was often overwhelmed during storms leading to raw sewage being dumped into the Chicago Area Waterway System (CAWS). Beginning in the late 1930s, separate sanitary sewer and storm sewer systems were constructed as the Chicago area continued to expand and develop minimizing the amount of wastewater to be treated and therefore limiting the dumping of raw sewage into the waterway. This allowed stormwater runoff to be handled by separate sewer or drainage systems not tributary to MWRD treatment plants, except for a limited amount of groundwater infiltration entering the sewers through pipe joints. However, over time the system has deteriorated resulting in the increased inflow of clearwater into the sanitary sewer system. The major sources of clearwater entering the sanitary sewer systems are groundwater infiltration and stormwater inflow (I/I). Excessive I/I can overload sewers particularly during wet weather leading to waterway pollution, basement sewage backups, reduced sewer capacity intended for sanitary sewage resulting in additional sewage treatment demand and overloading of the system. Full implementation of the sewer rehabilitation plan is expected to reduce the inflow of clearwater into sanitary sewers by over 50 percent.

These initiatives, in addition to TARP, not only address local issues but should significantly decrease the frequency and volumes of untreated storm and wastewater entering the canal system and ultimately Lake Michigan because of reversals through the WPS, CHL,the CRCW, and the T.J. O'Brien Lock and Controlling Works

3-02. Construction. In 2022, funding of approximately $50M was allocated for major rehabilitation of the T.J. O'Brien Lock. The rehabilitation effort is currently underway. A summary of projects dating back to 1970 can be found in Plate 3-1.

a. Chicago River Controlling Works. CRCW North has not been modified since its original construction. CRCW South was modified in 1999 by the state of Illinois Department of Natural Resources contract Chicago inner Harbor Turning Basin cutoff wall FR-404.

b. Chicago Harbor Lock. Since original construction of the lock, there have been several major rehabilitation or improvement projects. Those that occurred since the project was turned over to the Corps are given in Table 3-1 of the Chicago Harbor Lock Water Control Manual.

c. Wilmette Pumping Station. The Wilmette Pumping Station and Lock was constructed in 1910. The structure contained four propeller pumps, each with a capacity of 250 cfs at three feet of head. The navigation lock was located along the south side of the pumping station. The lock was 140 feet long and 11 feet deep. The width of the lock varied from 28 feet at -11 feet CCD to 30 feet at -5 feet CCD. The lock was designed to allow passage of small boats from the North Shore Channel to Lake Michigan. The lock was taken out of service in 1959 at which time the upper and lower lock gates were removed with the lower gate being replaced by a sluice gate 16 feet high by 32 feet wide. Repairs were made to the pump house intake walls in 1964.

Over time, the pumps fell into disuse and the pump bays were ultimately sealed in 1993 to reduce leakage from Lake Michigan. During that period, water was diverted into the North Shore Channel by raising the sluice gate. MWRD rehabilitated one of the pumps in 2002 to provide adequate pumping capacity for maintaining water quality while minimizing the opening of the sluice gate. The Wilmette Pumping Station, beginning the fall of 2011 and finishing fall of 2013, was rehabilitated as described in section 2-05c.

d. Thomas J. O'Brien Lock and Controlling Works. The Thomas J. O'Brien Lock and Controlling Works were built in 1959, eventually replacing the Blue Island Lock and Controlling Works in 1965 as the controlling structure between Lake Michigan and the Little Calumet River. The principal components of the facility include a navigation lock 110 feet wide by 1,000 feet long and four sluice gates 10 feet wide by 10 feet high with a sill elevation of -17.0 feet CCD.

e. Lockport Controlling Works. The Lockport Controlling Works was constructed by the MWRD over the period of 1895 to 1901. The original construction consisted of 15 sluice bays, seven of which were equipped with gate mechanisms, and a 160-foot-long moveable dam referred to as the Bear Trap Dam. The major structural steel components in the Bear Trap Dam were later removed and the dam was replaced by an earthen dam with a concrete core in 1938. The eight unused sluice bays were bulkheaded with concrete. The operating mechanisms for the seven operable sluice gates were replaced in 1956.

f. Lockport Lock. The Lockport Lock was designed by the State of Illinois and partially constructed over a period from October 1923-1930. With approximately 97 percent of the project completed, it was turned over to the Federal Government by authority of the Rivers and Harbors Act of July 3, 1930. The Federal Government completed construction of the Lockport Lock in 1933.

g. Lockport Powerhouse. The Lockport Powerhouse was constructed by the Chicago Sanitary District over the period from 1905 to 1907. The powerhouse was originally constructed with nine bays, seven of which were equipped with turbines and generators and one with turbines and exciters. Since then, four of the bays have been bulkheaded, two have been retrofitted with vertical shaft turbine generators, and three have had their components replaced with sluice gates.

3-03. Related Projects

a. Lake Michigan Diversion. The diversion of waters from Lake Michigan is an essential element in the maintenance of navigational activities for the upper portion of the Illinois Waterway. The diversion program has gone through numerous administrative and legal changes since the first diversion which occurred in 1848. Navigation of the Illinois-Michigan Canal required an annual diversion of approximately 500 cfs. This diversion rate was maintained over a period from 1848 to 1900 until the opening of the Chicago & Sanitary Ship Canal.

Diversion was progressively increased from 2,000 cfs in 1900 to approximately 10,000 cfs in 1928. In 1922, the State of Wisconsin, concerned about the effects of diversion that might lower Lake Michigan levels, successfully sought an injunction to prohibit the State of Illinois from diverting Lake Michigan water. In 1925, the United States Supreme Court overturned the injunction allowing diversion at an average rate of 8,500 cfs in addition to domestic pumpage. This decision was subject to conditions set by the War Department.

In 1930, the Court issued an additional decree requiring that the State of Illinois and the MSDGC gradually reduce the diversion of water from Lake Michigan, in addition to domestic pumpage, down to an annual average of 1,500 cfs by December of 1938. This time frame was intended to allow the MSDGC enough time to construct new sewage treatment facilities to replace the need for larger diversions for dilution. The total average annual diversion, with domestic pumpage included, was approximately 3,100 cfs. In 1967, the Supreme Court issued a decree limiting the diversion by the State of Illinois and its municipalities to an average of 3,200 cfs including domestic pumpage, over a five-year period effective March 1, 1970. The decree established Lockport as a measuring point for diversion accounting.

In December of 1980, the 1967 decree was modified with regard to the diversion accounting procedures; however, the 3,200 cfs diversion rate was maintained. New provisions of the decree allowed for an extended period for determining the running average diversion rate from five years to 40 years and changed the beginning of the accounting year from March 1 to October 1. The modified decree also increased the limitation on the average diversion in anyone accounting year to 3,680 cfs, with the exception that in any two annual accounting periods the annual diversion may not exceed 3,840 cfs to allow for extreme hydrologic conditions. In addition, a limit was placed on the cumulative algebraic sum of the annual diversions minus 3,200 cfs during the first 39 years to 2,000 cfs/year. The 3,680 cfs annual diversion limitation prevents the State of Illinois from banking a 2,000 cfs/year credit within the 40-year averaging period and then diverting a substantially larger amount of water in subsequent years. The 3,840 cfs limitation recognizes that there might be sufficiently extreme events that necessitate a larger diversion but limiting the State to two such events within an averaging period.

Until 1987, the State of Illinois was the lead agency responsible for the measurement and computation of water diversion from Lake Michigan at Chicago. As a result of the December 1, 1980 modification to the 1967 Supreme Court Decree, the Corps of Engineers was given an expanded supervisory role in the accounting procedures, data recording, and periodic investigation and calibration of the measuring devices. A final provision of the decree required that, at least every five years, the Chief of Engineers appoint a 3-member technical committee to determine the best current engineering practice and scientific knowledge for measuring the diversion. The Water Resources Development Act of 1986 (Section 1142 of Public Law 99-662) gave the Corps the legislative authority to take over the diversion accounting process from the State of Illinois effective 1 October 1987. The U.S. Geological Survey (USGS), through a cooperative agreement with the State of Illinois until 1987, now with the Corps of Engineers, maintains the current flow measurement system (an acoustic Doppler velocity measurement system) for the determination of the total flow in the waterway at Lockport. These flow measurements are a primary component of the Lake Michigan Diversion accounting system.

b. Tunnel and Reservoir Plan. Due to waterway pollution and the increasing flood control problems of the Metropolitan Chicago Area, the MWRD Tunnel and Reservoir Plan (TARP) was developed. The water management goals of the TARP are to prevent backflow of polluted river water into Lake Michigan, achieve water quality standards for the inland waters, and provide flood control. The main components of TARP include the Deep Tunnel System, coupled with reservoirs, drop shafts, connecting structures, pumping stations, and other appurtenances. The Deep Tunnel System consists of 109.4 miles of deep tunnel bored into rock and lined with concrete, 200 to 350 feet below the surface. The reservoirs are located at the downstream end of the tunnel systems to provide additional storage capacity. After a storm event, pumping stations dewater the tunnel systems as WRP capacity becomes available, making the tunnel and reservoir capacity available for the next storm event. All captured combined sewer flow pumped to the WRP receives full secondary treatment prior to being discharged to the waterway pursuant to the National Pollutant Discharge Elimination System permits. This design feature will reduce the need to divert dilution water from Lake Michigan which currently represents approximately 8% of the annual diversion budget. Stored water in the TARP system will also reduce the quantity of water required for navigational make-up. Both reductions will allow a more efficient allocation of Lake Michigan water for domestic purposes. The TARP system layout and routes are shown in Plate 2-10.

The construction of TARP has been divided into two phases. Phase I consists of the deep tunnels and Phase II consists of the reservoirs. A majority of the water quality benefits are associated with TARP Phase I, whereas Phase II is primarily for flood reduction.

1. Phase I of TARP. The first phase, intended primarily for pollution control, is made up of four district tunnel systems: Mainstream, Des Plaines, Calumet, and Upper Des Plaines. Collecting structures divert combined sewer overflows away from the watercourses and into the dropshafts. The tunnel conveys the combined sewage to the pump station located at the head of end of the tunnel. The pump stations will permit a rate of dewatering of the tunnels which will allow a full tunnel to be emptied within two to three days. Construction of Phase I tunnel systems commenced in 1975 and they were put into service as portions were completed, starting in 1984. By 2006, all of Phase I was completed and in operation. The total system consists of 109.4 miles of deep, large diameter, rock tunnels providing 2.3 billion gallons (BG) (7058 acre-feet) of volume to capture CSOs that previously discharged at hundreds of outfall locations.

The Mainstream TARP system consists of 40.3 miles of Phase I tunnel. The drainage area associated with the Mainstream Phase I tunnel is 219.9 square miles. At the terminal end of the Phase I tunnel a pump station has been constructed to dewater the Mainstream and Des Plaines Phase I tunnels. The pump station will also dewater the McCook quarry reservoir. The pump station lifts the tunnel volume up to the Stickney Water Reclamation Plant for treatment prior to being discharged to the Chicago Sanitary and Ship Canal.

The Des Plaines system consists of 36.3 miles of Phase I tunnel. The Phase I tunnel storage is equal to 413 MG (1267 acre-feet). Combined sewer overflow from the 34.8 square mile Des Plaines will be collected and treated as in the Mainstream System prior to being discharged to the Sanitary and Ship Canal.

The Calumet TARP system consists of 36.3 miles of Phase I tunnel with a storage capacity of 534 MG (1638 acre-ft). The sanitary flow generated by the Calumet system is collected and treated at the Calumet Water Reclamation Plant. Wet weather flows greater than the capacity of the interceptor sewers or Calumet Water Reclamation Plant are diverted into the watercourses (Calumet-Sag Channel, Little Calumet River, and Grand Calumet River). The proposed TARP project will provide for the collection and treatment of the combined sewer overflows at this system.

2. Phase II of TARP. The second phase consists of an additional 17.3 miles of Mainstream tunnel, 4.2 miles of Calumet tunnel, an on-line reservoir and two terminal reservoirs located at the downstream end of the Mainstream/Des Plaines and Calumet tunnels. The purpose of the terminal reservoirs is to permit the retention of a greater quantity of combined sewer overflow volume intended primarily for flood control, considerably enhancing pollution control benefits being provided under Phase I. The Chicagoland Underflow Plan (CUP), Final Phase I General

Design Memorandum (GDM) of 1986 defined the Federal interest in TARP Phase II based on the Federal National Economic Development Plan criteria. The three reservoirs proposed under TARP Phase II/CUP are: the O'Hare, McCook, and Thornton Reservoirs mentioned above. When all three reservoirs are completed, the reservoirs will increase the TARP system storage volume to 17.5 BG (53,705 acre-feet).

The 350 MG (1,074 acre-feet) O'Hare CUP Reservoir was completed by the Corps of Engineers, Chicago District in 1998, at a cost of $45 million. Since its completion, the O'Hare CUP Reservoir, renamed the Majewski Reservoir in 2010, has yielded $350 million in flood damage reduction benefits to the three communities it serves. The McCook Reservoir is currently under construction and, when completed, the reservoir will have a total capacity of 10 BG (30,689 acre-feet). Phase I of the reservoir was completed in 2017 providing 3.5 BG (10,741 acre-feet) of storage, and Phase II is scheduled to be completed by 2029 providing an additional 6.5 BG (19,948 acre-feet). The McCook Reservoir will provide over $90 million per year in flood damage reduction benefits to 3,100,000 people in 37 communities.

The Thornton Reservoir is being constructed in two stages. The first stage, a temporary 3.1 BG (9,513 acre-feet) Natural Resources Conservation Service (NRCS) reservoir called the Thornton Transitional Reservoir, was completed in March 2003 in the West Lobe of the Thornton Quarry. The second stage is a permanent 7.9 BG (24,244 acre-feet) combined NRCS/CUP reservoir, called the Thornton Composite was completed in 2015 and provides $40 million per year in benefits to 556,000 people in fifteen communities. A portion of the total storage volume is allocated to MWRD for CSO capture; the remainder is retained by NRCS for storing floodwaters from Thorn Creek. The Thorn Creek Overflow Tunnel was connected to the Thornton Composite Reservoir and the Thornton Transitional Reservoir was decommissioned in September 2022.

c. Acoustical Velocity Meter Gaging Station. An acoustical velocity meter (AVM) gaging station was operated by the U.S. Geological Survey in cooperation with the Illinois Department of Transportation during the periods prior to 1988, and later, with the Corps of Engineers. Its purpose was to record flows through the Chicago Sanitary and Ship Canal for use in the Lake Michigan Diversion accounting computation. According to the manufacturer, the accuracy of the AVM records was to be within 2%. The gage was originally located on the Chicago Sanitary and Ship canal at River Mile 296.1, on the left upstream side of the 135th Street bridge, 1.3 miles east of Romeoville, Illinois. Due to the installation of the electrical dispersal barrier II on the CSSC at Romeoville, the AVM was relocated to Lemont, approximately six miles upstream from the Romeoville site, in 2006. The elevations of the controlling features are listed in Table 3-1 and illustrated in Plate 3-2. The location of the gage is shown on Plate 3-3.

The Chicago Sanitary and Ship Canal channel at the AVM station, has a relatively flat bottom with near vertical walls and a depth of 25 feet at normal elevation. The water levels are controlled by the operations of the hydroelectric generators and sluice gates at Lockport Powerhouse and the Controlling Works, located downstream of the gage location at river miles 291.0 and 293.2, respectively. When heavy rains are forecasted, the discharges at Lockport are increased to provide efficient drainage for flood waters from the Metropolitan Chicago area.

Table 3-1 Elevations of Controlling Features, AVM at Lemont

Velocity Path No. 3 (lowest transducer)	8.1
Velocity Path No. 2 (middle transducer)	13.5
Velocity Path No. 1 (highest transducer)	18.7
	Dimension (feet)
Length of Paths[b]	229

[a] Gate at datum 551.5 NAVD88
[b] AVM path oblique: the path length is greater than the channel width

d. Acoustical Doppler Velocity Meter Gaging Station. An acoustic Doppler velocity meter (ADVM) gaging station was installed by the U.S. Geological Survey in May 2014 and became the primary monitoring device at the Chicago Sanitary and Ship Canal at Lemont.

3-04. Principal Regulation Issues. During periods of extreme lake levels, both high and low, operating the CSSC in accordance with the water control plan becomes problematic. When the lake level reaches a point at which it is below the authorized depth of the canal, the head differential across the lakefront structures would result in the Chicago River reversing again, with its flow discharging to the lake. Due to the inadequacy of the water quality of the Chicago River, however, this would not be permissible by the State of Illinois. It’s therefore necessary to operate the Chicago River and adjoining waterway system at a lower level to prevent backflows into the lake.

During periods of high lake levels, specifically those times when the lake is above 3.0 feet CCD, the stage in the Chicago River at which a backflow is imminent, the reduced head differential between the lake and the river allows for a reduced backflow capacity at the lock. When the lake level reaches 3.5 feet CCD at CRCW and T.J. O’Brien Lock and Controlling Works, the point at which a backflow occurs, the river must rise above this point prior to a backflow being attempted. Here again, the diminished head differential between the river and the lake minimizes the capacity during a backflow event, significantly reducing the flood damage reduction benefits of such an operation.

Commercial navigation problems are related to the drawdown of the waterway at Lockport. Without warning, rapid drawdown may be required during storm (either in progress or impending), increasing the flows at the Lockport Powerhouse. The rapid drawdowns with associated rapidly changing flows are sometimes necessary during storm conditions. Navigational interests in the reaches should be aware of these conditions and be adequately prepared. When this occurs, there is an increased potential for barges to break loose from their moorings making control of barge tows on the canal more difficult.

3-05. Invasive Carp Threat. Bighead and silver carp, commonly referred to as invasive carp, were first introduced in the United States for the purpose of controlling algae in ponds. During flooding of 1994 bighead carp escaped from an aquaculture farm and began spreading throughout the Mississippi River Basin. In October 1996, the National Invasive Species Act passed amending the Non-indigenous Aquatic Nuisance Prevention and Control Act of 1990 and directing the Corps to construct a Demonstration Barrier on the CSSC. Invasive carp were first sampled from the Illinois River during the 1990s and populations have since progressed upstream. There is a potential threat of invasion of the Great Lakes by bighead carp and silver carp with the CSSC serving as a pathway.

Barrier I, constructed near Romeoville, Illinois, otherwise known as the Demonstration Barrier, came online April 2002. During monitoring efforts in 2002, invasive carp were detected in the upper Illinois River just 60 miles from Lake Michigan. Upgrades were made on Barrier I in October 2008 and Barrier IIA came online April 2009. In 2009, a bighead carp was retrieved only 43 miles from Lake Michigan. This event along with additional monitoring in the area triggered a rapid response rotenone operation (fish kill) during barrier maintenance in December 2009 to block invasive carp passage through this area. In June 2010, one bighead carp was found in Lake Calumet, 5 miles from Lake Michigan though its origin and route of entry is unknown. Barrier IIB was brought online in April 2011. The combination of these three barriers is designed to function together to prevent inter-basin transfer of fish between the Mississippi River and Great Lakes drainage basins.

Through the Water Resources Development Act of 2007, Congress directed the Corps to study various technical, environmental, and biological factors that could potentially compromise the effectiveness of the existing barriers. The first report the Corps completed under this authority identified areas of potential bypass of fish through neighboring waterways upstream of the electronic barriers on the CSSC during flooding and recommended construction of a barricade along the Des Plaines River where spillover between the two basins had occurred previously. The fence extends approximately 13 miles from Romeoville, Illinois to Willow Springs, Illinois. The barrier was built to allow the flow of water during flood conditions while preventing both juvenile and adult invasive carp from bypassing the Dispersal Barrier via overland flow from the Des Plaines River to the CSSC. The barrier was completed in October 2010, along with a stone blockage in the I&M Canal, completed in June 2010. During the July 24-25, 2010 heavy rainfall event in the Chicago area, the completed I&M Canal blockage and the completed portions of the fence along the Des Plaines River functioned as designed and prevented unimpeded flow of water at connections closest to the electric barriers.

The 2011 Monitoring and Rapid Response Plan (MRRP) incorporates preliminary results of 2010 invasive carp monitoring and removal efforts, extensive discussions among action agency staff and Monitoring and Rapid Response Work Group (MRRWG) technical experts, and numerous written comments provided by workgroup members, Great Lakes state's natural resource agencies, and non-governmental organizations. The current plan includes a review of previous plan development in light of 2010 sampling results, updated and more focused goal and strategic objectives, discussion of tools available to complete necessary work, and individual project plans detailing tactics and protocols that will allow the Corps to achieve the overall goal and accomplish strategic objectives. The overall goal is to prevent invasive carp from establishing self-sustaining populations in the Chicago Area Waterway System (CAWS) and Lake Michigan.

In January 2014, the Corps completed the Great Lakes and Mississippi River Interbasin Study (GLMRIS). The study report presented technologies to control Aquatic Nuisance Species (ANS) including invasive carps. The report also presented eight alternative plans to prevent the spread of 13 ANS including options to separate the hydrologic connection between the Lake Michigan and Mississippi River basins.

In 2015, the Brandon Road Lock and Dam near Joliet, Illinois, was identified as a critical pinch point where layered technologies could be used to prevent movement of invasive carp populations into the Great Lakes. A feasibility study was completed in 2019 and its recommended plan was authorized by congress for implementation. The project was coined the Brandon Road Interbasin Project (BRIP) which comprises a series of fish deterrent technologies including acoustic fish deterrent system, bubble curtain system, electric barrier system, an engineered channel, and flushing lock. The estimated total project cost is $1.146B. The leading edge of deterrents (Increment I-A) has been fully designed and on target for a 2024 construction.

3-06. Water Quality. In 1972, MWRD proposed a system of artificial aeration stations in the CAWS for maintaining oxygen at or above the applicable DO water quality standard corresponding to the newly defined water use designations. The principle behind artificial aeration is that oxygen is transferred to a waterway by mechanical or other means before the DO concentration has decreased below the oxygen standard. The first artificial aeration design considered by MWRD for the waterways focused on diffuser systems. In diffuser systems (in-stream aeration), oxygen is transferred to the water column by passing compressed air through porous ceramic diffuser plates placed on the bottom of a waterway.

In the late 1970s, two in-stream aeration stations became operational, one in the North Shore Channel (Devon Avenue) and the other in the North Branch of the Chicago River (Webster Street). In the late 1980s, an improved design for artificial aeration was proposed by the MWRD. The improved design was known as side stream elevated pool aeration (SEPA). SEPA involves low head pumping of water by means of screw pumps up a series of elevated shallow side stream pools linked by waterfalls. During the period of 1993-1995, five SEPA stations were constructed and became operational along the Calumet Waterways. One SEPA station is located in the Calumet River (River Mile 328.1), one station is in the Little Calumet River (River Mile 321.2), and three SEPA stations are in the Calumet-Sag Channel (River Miles 318.0, 311.5, and 303.7).

During the 1990s, as water quality gradually improved, areas along the CAWS developed including residential, parks, and retail. Numerous docks and ramps were put in as more and more people were using the waterways for recreation. A provision in the Clean Water Act mandates that water quality standards below fishable and swimmable standards be re-evaluated if the conditions and usage on a waterway change over time and if the "fishable and swimmable" goal is attainable.

Noticeable water quality improvement, including lower contaminant levels and the completion of the tunnel phase of TARP, compelled the EPA to conduct a User Attainability Analysis (UAA) on the Chicago Area Waterways from 2002-2007. On September 9, 2011, the State of Illinois finalized new water quality standards to protect recreational uses for waters within the Chicago Area Waterway. The EPA had previously notified the State of Illinois in May 2011that water quality standards for portions of the Chicago and Calumet Rivers must be upgraded to protect the health and safety of people who recreate in these waterways. Consequently, MWRD has agreed to disinfect water discharged from the Calumet and O'Brien Water Reclamation Plants.

The Illinois Pollution Control Board has adopted four new categories of recreational use designation for the Chicago Area Waterway System (CAWS) and Lower Des Plaines River (LDPR): Primary Contact Recreation, Incidental Contact Recreation, Non-Contact Recreation, and Non-Recreational. In addition, rules were also added defining the recreational use designation, "Primary Contact Recreation", to identify segments of the CAWS where full body contact recreation is attainable in the foreseeable future. Primary Contact Recreation is intended to meet the CWA recreational use goal of recreating on and in the water (swimmable). The following waters are now designated as Primary Contact Recreation Waters and must be protected as such.

a) Lower North Shore Channel from O'Brien Water Reclamation Plant to confluence with North Branch of the Chicago River; continuing to the confluence with South Branch of the Chicago River and Chicago River; the Chicago River; South Branch of the Chicago River.

b) Little Calumet River, from its confluence with the Calumet River and Grand Calumet River, to its confluence with the Calumet-Sag Channel, and along the Calumet-Sag Channel.

The designation "Non-contact Recreation" is defined as any recreational or other water use in which human contact with the water is unlikely, such as pass through commercial or recreational navigation, and where physical conditions or hydrologic modifications make direct human contact unlikely or dangerous. The Calumet River from Lake

Michigan to Torrence Avenue is now designated “Non-contact Recreation” Waters and must be protected as such.

“Incidental Contact Recreation” means any recreational activity in which human contact with the water is incidental and in which the probability of ingesting appreciable quantities of water is minimal, such as fishing, commercial boating, small craft recreational boating, and any limited contact associated with shoreline activity such as wading. The following waters are designated as Incidental Contact Recreation Waters and must be protected as such.

a) Upper North Shore Channel from Wilmette Pumping Station to O’Brien Water Reclamation Plant; South Fork of the South Branch of the Chicago River (Bubbly Creek);

b) Chicago Sanitary and Ship Canal from its confluence with South Branch of the Chicago River to its confluence with Calumet-Sag Channel.

c) Calumet River form Torrence Avenue to its confluence with Grand Calumet River and Little Calumet River; Lake Calumet and Connecting Channel; Grand Calumet River.

d) Lower Des Plaines River from the Brandon Road Lock and Dam to the I-55 Bridge.

In addition to the requirement for disinfection, MWRD is studying additional aeration systems to increase dissolved oxygen levels where needed, corresponding to the new water use designations given above.

WATERSHED CHARACTERISTICS

4-01. General Characteristics. The Chicago Sanitary and Ship Canal (CSSC) runs in a southwesterly direction from the South Branch of the Chicago River to approximately one mile south of the Lockport Lock and Dam. Typically, the level of Lake Michigan is higher than that of the Chicago River, creating a hydraulic gradient away from the lake. Prior to the construction of the CSSC and the Calumet-Sag Channel, approximately 673 square miles, or 91 percent of the watershed drained to Lake Michigan via the Chicago and Calumet River systems. The remaining 67 square miles were part of the Des Plaines River Watershed until the area was cut off by the canal. The canal watershed boundary, consisting of the diverted portion of the Lake Michigan Watershed and the diverted portion of the Des Plaines River Watershed, is shown on Plate 2-1.

The principal waterways of the watershed are the Chicago River system, the Chicago Sanitary and Ship Canal, the North Shore Channel, the Calumet River system, and the Calumet-Sag Channel. The Chicago River system includes the Chicago River, the North Branch of the Chicago River, and the South Branch of the Chicago River. The Calumet River system includes the Calumet River, the Little Calumet River, and the Grand Calumet River. Principal waterways of the watershed are shown on Plate 2-1.

The maximum regulatory pool elevation of the CSSC is 583.0 feet NGVD (+3.5 feet CCD at CRCW and O'Brien; + 5.0 feet at Wilmette). Under extreme weather conditions, when enough lead time is not available to drawdown the canal for additional stormwater storage, this elevation may be exceeded, resulting in temporary flooding within the metropolitan area. A last resort to avoid severe flooding is to discharge stormwater to Lake Michigan. Water may be discharged to Lake Michigan at the Wilmette Pumping Station, the Chicago Harbor Lock (CHL), the Chicago River Controlling Works (CRCW), and the Thomas J. O'Brien Lock and Controlling Works. Discharging excess stormwater to Lake Michigan minimizes the potential for severe flooding along the Chicago Area Waterway. Exhibit C details the procedures used to regulate the stages within the Chicago Area Waterway System (CAWS) above Lockport, Illinois.

4-02. Topography. The topography of the watershed is generally flat in the Chicago metropolitan area near the lake and becomes gently rolling from the central to the western area further inland. Surface elevations vary from low points of 580 NGVD (+0.5 feet CCD) along Lake Michigan and 545 feet NGVD (-34.5 feet CCD) immediately downstream from the Lockport Lock, to a high elevation of 750 feet NGVD (170.5 feet CCD) at the southeastern watershed boundary in Section 25, Township 37 North, Range 11 East, in the Town of Lemont, Illinois.

The CSSC is contained within a river valley approximately one mile wide which extends northeast from the Lockport Lock to the Village of Summit, Illinois, paralleling the Des Plaines River along the right bank of the canal. The topography in this area is generally rolling with a relatively flat floodplain within the river valley. Beyond the village of Summit, Illinois the Des Plaines River turns to the north and the CSSC continues within a narrow river valley through the Chicago metropolitan area to the South Branch of the Chicago River, which joins the Chicago River at Wolf Point, which in turn connects to

Lake Michigan to the east. The North Branch of the Chicago River starts up in Lake County and flows to the south and east to the junction with the North Shore Channel, which extends northerly to Lake Michigan at Wilmette, Illinois. Downstream of the North Shore Channel junction, the North Branch of the Chicago River continues south and east through the City of Chicago to the junction with the Chicago River at Wolf Point. Prior to the reversal of the Chicago Area Waterway, runoff from the North and South Branches flowed into the Chicago River and into Lake Michigan. The Calumet-Sag Channel, which connects to the Calumet River on the south side of Chicago, Illinois, enters the CSSC at River Mile 303.4, at the Cal-Sag junction. The topography changes to moderately sloped and flat sloped in areas to the east as the channel enters the Calumet River system. Prior to the reversal, the Calumet River flowed into Lake Michigan.

4-03. Geology and Soils. Soils in the watershed are formed mainly in glacial material. Predominant soils are high in silt and clay. The most dominant soil group is the silty and clayey soil found on uplands and lake plains. The major soils within this group are the Markham Ashkum, Morley Frankfort, Bryce, and Milford soils. They range from poorly to well drained and are moderately to slowly permeable.

Immediately adjacent to the CSSC and the Calumet-Sag Channel, soils are silty and loamy on terraces and bottom lands. The most dominant soil found within this group is the Faxon-Kankakee-Rockton unit. These soils are moderately deep level and gently sloping, poorly drained to well drained soils that have loamy or silty subsoil. Soils adjacent to the Little Calumet and Calumet Rivers are sandy and loamy soils on uplands. The most dominant soil within this group is the Selma-Oakville unit. These soils are found on built-up areas and are deep, level to undulating, well drained and poorly drained soils that have loamy, silty, or sandy subsoil. These soils are found in glacial outwash and in glacial lake sediment. There are lesser amounts of numerous other soil groups found within the watershed.

4-04. Sediment. The Environmental Monitoring and Research Division of Metropolitan Water Reclamation District (MWRD) oversee the Ambient Water Quality Monitoring (AWQM) network associated with the Chicago Area Waterways System. Water quality is discussed in Section 4-08. Detailed annual AWQM biological, habitat, and sediment reports have been published by MWRD since 2001. In addition, MWRD prepares 4-year summary reports. The data are used to support the Illinois Environmental Protection Agency (IEPA)'s efforts to make regulatory decisions, prepare 305 (b) reports in accordance with the Clean Water Act, and to prepare Use Attainability Analysis (UAA) for the components of the waterways.

In October 2000, the U.S. Environmental Protection Agency (USEPA) and the U.S. Army Corps of Engineers (USACE) coordinated a baseline screening study to provide a broad view of sediment conditions throughout the Chicago River system, specifically the North and South Branch, while targeting depositional zones within the river. The study showed polycyclic aromatic hydrocarbons (PAHs), oil and grease, dioxins, and furans and polychlorinated byphenyls (PCBs) are the primary contaminants of concern, with metals a secondary contaminant of concern. Elevated PAH levels, especially in the South Branch of the river were present potentially presenting an ecological and/or human health threat. The presence of heavy metals including cadmium, copper, chromium, lead and zinc indicated high levels of contamination, but based upon SEM/AVS analysis during this survey these metals were not found to be bioavailable to the benthic community in the surficial sediment except in locations on the South Branch of the river. PCB concentrations appear to be higher in the deeper sediments of the North Branch of the River. Overall, the surficial sediments are less contaminated than the deeper sediments throughout the river system.

There are several physical characteristics within CAWS, particularly in the developed areas, that constrain the habitat and aquatic life including channelization, limited instream vegetation and canopy cover, siltation, erosion, and lack of adequate flood plain area. However, with TARP online, the amount of untreated combined sewer overflows (CSOs), including industrial wastewater, entering the waterways has been significantly reduced. In addition, the number of fish species present in the Chicago and Calumet River Systems increased from around 10 in 1974 to around 70 in 2006. The increases correlate with the implementation of Tunnel and Reservoir Project (TARP) beginning in the mid-1980s and the implementation of Side-stream Elevated Pool Aeration (SEPA) stations in the 1990's.

An extensive Use Attainability Analysis (UAA) was completed in 2007 to reevaluate water use designation as conditions had changed significantly since the Clean Water Act had first been implemented. After further study the IEPA suggested revised water use designations in May of 2011 and MWRD subsequently agreed to pursue disinfection of effluent at the Northside and Lemont Water Reclamations Plants in June of 2011. In September of 2011 the state of Illinois finalized new water quality standards and the adoption of four new water use designations as described in section 7-07. Additional studies are underway to evaluate alternatives to meet additional aeration requirements necessary to comply with the newly adopted water use designations. Although the Chicago River and Harbor are routinely monitored using bathymetric surveys, there has been little need for dredging within either waterway. In many places along the waterway the deeper layers of sediment are contaminated due to accumulation of pollutants over the years.

4-05. Climate. The Chicago Area is in a region of frequently changing weather. The climate is predominately continental, ranging from relatively warm in summer to relatively cold in winter. However, the climate is partially modified by Lake Michigan and to a lesser extent by the other Great Lakes. In late autumn and winter, air masses that are initially very cold often reach the city only after being tempered by passage over one or more lakes. Similarly, in late spring and summer, air masses reaching into the city from the north, northeast, or east are cooler because of movement over the Great Lakes. Very low winter temperatures most often occur in air that flows southward to the west of Lake Superior before reaching the Chicago area.

In summer the higher temperatures are generally associated with south or southwest flow. However, when the lake is cold relative to land, there is frequently a lake breeze that reduces daytime temperature near the shore, sometimes by 10 degrees or more below temperatures further inland. When the breeze off the lake is light this effect usually reaches inland only a mile or two, but with stronger onshore winds the whole city is cooled. On the other hand, temperatures at night are warmer near the lake so that 24-hour averages overall are only slightly different in various parts of the City and suburbs.

Strong south or southwest flow may overcome the lake breeze and cause high temperatures to extend over the entire City. In addition, a combination of high temperature and humidity may develop, usually building up progressively over a period of several days when winds continue out of the south or southwest, becoming oppressive for one or perhaps several days, then ending abruptly with a shift of winds to northwest or northerly. The change may be preceded or accompanied by thundershowers.

Precipitation falls mostly from air that has passed over the Gulf of Mexico. But in winter there is sometimes snowfall, light inland but locally heavy near the lakeshore, with Lake Michigan as the principal moisture source. The heavy lakeshore snow occurs when initially colder air moves from the north with a large trajectory over Lake Michigan and impinges on the Chicago lakeshore. In this situation the air mass is warmed, and its moisture content increased up to a height of several thousand feet. Snowfall is produced by upward currents that become stronger, because of frictional effects, when the air moves from the lake onto land. This type of snowfall therefore tends to be heavier and to extend farther inland in south-shore areas of the City and in Indiana suburbs, where the angle between wind-flow and shoreline is greatest. The effect of Lake Michigan, both on winter temperatures and lake-produced snowfall, is enhanced by much of the lake not freezing over during the winter, even though areas and harbors are often ice-choked. This type of local heavy snowfall may occur once or a few times in a normal season. Summer thundershowers are often locally heavy and variable, with parts of the city receiving substantial rainfall and other parts none. Longer periods of continuous precipitation are mostly in autumn, winter, and spring. About one-half of the precipitation falls in winter, and about 10% of the yearly total precipitation falls as snow. Snowfall from month to month and year to year is greatly variable.

Climactic changes in regional hydrologic trends, characterized by increasing periods of reduced precipitation and more frequent and severe storm events is an issue under investigation by state and federal agencies. Although these changes may impact the frequency at which waterway responses to flood forecasts or storms are implemented, it is not expected to change the overall water control plan.

a. Temperature. The average annual temperature in the Chicago area is approximately 51° Fahrenheit (F). Seasonal weather meets a high degree of variation as average winter highs dip to the mid-30s with average lows around 20°F. Likewise, average summer highs reach the mid-80s while seasonal lows average in the middle 60s. Fall and spring often see major fluctuations in temperature, but both average highs around 60°F, while lows often hover around 40°F. Temperatures of 90°F or higher occur 16 days a year on average in Chicago, Illinois while the temperature drops below 0°F 8 days a year on average. Normal daily mean temperatures are below 32°F for 88 days during winter. The normal heating season is mid-September to early June. Over 90 percent of the normal heating load is between October 1 and April 30.

Table 4-1 Temperatures in Degrees Fahrenheit 1981-2019

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Chicago O'Hare													
Record High	65	72	88	89	97	104	104	101	99	88	75	71	104
Avg Max	31.1	34.7	46.5	58.1	70.8	80.4	84.7	82.5	76.0	62.5	47.4	38.8	59.4
Avg Mon	23.8	26.8	38.1	48.5	60.6	70.2	75.3	73.4	66.8	53.7	39.7	31.3	50.7
Avg Min	16.5	18.8	29.8	38.8	50.4	60.1	66.0	64.3	57.6	44.8	32.1	24.7	42.0
Record Low	-27	-19	-7	7	27	37	45	42	29	17	6	-25	-27

b. Precipitation. The annual mean precipitation in the Chicago area is 41.3 inches with extremes of 50.9 inches in 2008 and 22.2 inches in 1962. The daily record for Chicago O'Hare is 6.86 inches of rainfall on July 23, 2011. The annual mean snowfall is around 41.5 inches. The heaviest snowfall season total is 89.7 inches during the winter of 1978 – 1979 while the least snowy winter is 9.8 inches in 1920 – 1921. The record daily snowfall total is 18.6 inches on January 2, 1999. Precipitation and snowfall summaries for the Chicago area are listed in Tables 4-2 and 4-3, respectively.

Table 4-2 Precipitation in inches – Average, Maximum, Minimum 1981-2019

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Chicago O'Hare													
Max	4.5	5.6	5.2	8.7	8.3	10	11.2	17.1	13.6	8.7	8.2	8.6	50.9
Avg	2.0	2.4	2.4	4.2	5.5	4.6	4.5	4.0	3.2	4.0	2.4	2.2	41.3
Min	0.1	0.2	0.6	0.7	0.3	0.8	1.1	1.2	0.3	0.9	0.4	0.5	24.1

Table 4-3 Snowfall in inches – Average, Maximum, Minimum 1981-2019

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Chicago O'Hare													
Max	33.7	29	18.2	10.6	0.5	0	0	0	0	6.3	12.7	30.9	69.8
Avg	11.5	15.7	5	1.7	0	0	0	0	0	0.7	3.6	6.2	40.4
Min	0.4	0	0	0	0	0	0	0	0	0	0	0.4	0

4-06. Storms and Floods. All seasons are marked by storms that accompany the changes from one type of air mass to another. In winter, rain changes to sleet or snow, and occasionally thunder is heard at the height of a snowstorm. In summer, thunderstorms that are frequently heavy and occasionally accompanied by hail, and on rare occasions by tornadoes, mark these changes from one type of air mass to another. These thunderstorms have been sufficiently intense at times to raise water levels in the CAWS a significant amount within a relatively short period of time. The storm runoff events which occurred during October 3-12, 1954 and July 12-13, 1957 caused record flooding along the CAWS. These storms caused MWRD to revise the operating plan and ultimately played a major part in the decision to build and implement the TARP. A summary of reversals to Lake Michigan occurring since TARP first started to come online in 1985 is given in Plate 4-1. A summary of significant storms and floods are presented below beginning with the 1954 event.

a. Flood of 1954. Precipitation totals during the 1954 storm ranged from 5.6 inches at the 31st Street and Western Avenue gages, to 7.6 inches at the Calumet Treatment Plant. Peak canal water surface elevations of +9.4 feet CCD and +5.3 feet CCD occurred at the Wilmette Pumping Station and the mouth of the Chicago River, respectively. The Little Calumet River near the present site of the Thomas J. O'Brien Lock and Controlling Works peaked at +3.9 feet CCD. Peak elevations were reached at around 6PM on October 10 at which time the water level at the Lockport Powerhouse was at -5.0 feet CCD.

Serious flooding problems existed along the North Shore Channel in Evanston, Illinois, at Blue Island along the Calumet-Sag Channel, and along Wacker Drive in downtown Chicago. Flooding in downtown Chicago was especially severe in 1954. This caused a reevaluation of waterway operating procedures so that backflow is allowed into Lake Michigan when water surface elevations at the CRCW exceed +3.5 feet CCD instead of the previous value of +5.0 feet CCD.

b. Flood of July 1957. Only three years after record flooding in 1954, the storm of 1957, with 6 inches of rainfall recorded during a 12-hour period, caused record high water levels once again. The Wilmette Pumping Station reached +9.9 feet CCD, at Belmont Avenue it reached +6.80 feet CCD and at the mouth of the Chicago River it reached +3.80 feet CCD. The lock gates were opened at 10:20 PM on July 12, about two hours before the occurrence of peak elevations in the North Shore Channel and about two and a half hours before the occurrence of the maximum discharge at the Lockport Powerhouse and Controlling Works. Water surface elevations peaked at -35.6 feet CCD at the Lockport Powerhouse tailrace and at -39.4 feet CCD at the Brandon Road Lock and Dam pool gage. The replacement of the lock gates at the Wilmette Pumping Station with a sluice gate 32 feet wide by 16 feet high in 1959 increased the discharge capacity and thus offered greater relief for future storms in the North Shore Channel section of Chicago, Illinois.

c. Flood of 1975. An unexpected severe rainstorm occurred during the afternoon and evening of April 18, 1975 resulting in significant flooding in the Chicago area. The NWS recorded 3.83 inches at Chicago Midway Airport and the basin average for the District was reported as 2 inches. Flow reversals began in the evening at Wilmette and CRCW and eventually the Chicago Harbor Lock gates were opened for a few hours. The North Shore Channel at Wilmette reached +7.1 feet CCD and the Chicago River at the Chicago Harbor Lock was held to +3.5 feet CCD during this event. The high stage at Wilmette was due in part to temporary problems with gate operations. In a summary report, MWRD noted that increased runoff and faster rises in water levels occurring over time due to continuing development in the Chicago area.

d. <u>Flood of December 1982</u>. The flood of December 1982 resulted in reversals at all three control structures in Lake Michigan for the first time since 1957. Total rainfall for the period December 2-3 averaged 2.63 inches over the waterways. The total volume of the reversal was 515 MG (1,580 acre-feet) which was less than the capacity of the Tunnel system (830 MG; 2,547 acre-feet) funded to date (1982) under Phase I of TARP. This indicated that had the funded portion of the Tunnel system been implemented prior to the event the amount of the reversals would have been less and it is possible that the reversals at WPS and CRCW would not have been necessary.

e. <u>Flood of August 1987</u>. The flood of August 1987 was a major test for the Deep Tunnel system being built under Phase I of TARP which began coming on-line in 1985. Heavy rainfall moved into the area the night of July 13, with rainfall totals of 2.86 inches recorded by midnight at Chicago O'Hare Airport. By noon on July 14, a new daily record of 6.49 inches of rain had fallen bringing the rainfall total to 9.35 inches. Additional rainfall on July 16-17 resulted in a 4-day storm total of 12.84 inches at O'Hare. The average rainfall recorded by the MWRD gage network was 3.82 inches. The North and Central areas of MWRD's service area were hit the hardest, averaging 7.35 inches and 5.21 inches respectively, in contrast to the South area which only reported 1.03 inches. A total of 1.96 BG (6,015 acre-feet) was released into Lake Michigan while the Mainstream TARP system stored 1 BG (3,069 acre-feet) of combined sewer overflows that would have otherwise gone into Lake Michigan. Another storm moved through the area August 16-17, but the operation of TARP stored 0.4 BG (1,228 acre-feet) of combined sewer overflows, alleviating flooding and possibly preventing further releases into Lake Michigan.

The extensive flooding that occurred in the Chicago Metropolitan area during the 1986 and 1987 events led to legislation authorizing the formation of countrywide stormwater programs. This provided the structure to better manage and mitigate local drainage and flooding problems. Ultimately, these programs will help attenuate some of the pressure on the system.

f. <u>Flood of July 1996</u>. An average of 3.92 inches fell July 17-18, 1996, resulting in serious flooding problems along the North Shore Channel in Evanston, Illinois, the Calumet-Sag Channel, and along Wacker Drive in downtown Chicago, Illinois. The southern area reported 6.27 inches of rainfall on average resulting in record flooding along the Calumet-Sag Channel with the Cal-Sag Junction and the tailwater at Thomas J. O'Brien Lock and Controlling Works reaching +2.7 feet CCD and +4.3 feet CCD (a new record) respectively. The TARP tunnels were completely full and reversals to Lake Michigan totaling 1.5 BG (4,603 acre-feet) were required at the Chicago Harbor Lock and Chicago River Controlling Works (0.5 BG; 1,534 acre-feet) and Thomas J. O'Brien Lock and Controlling Works (1 BG; 3,069 acre-feet). The O'Hare Reservoir, now called the Majewski Reservoir, came on-line in 1994 as part of the Mainstream Tunnel system and stored 72 MG (221 acre-feet), 43% of its storage capacity.

g. Flood of July 1997. Rainfall totaling 2.7 inches on average fell over the CAWS over a 15-hour period beginning at 6 PM August 16, 1997. The heaviest rainfall occurred in the Central and North areas, causing significant flooding, especially along the North Shore Channel. The North Branch Pumping Station at Lawrence Street, located along the North Shore Channel, reached +9.3 feet CCD on July 16, 4.1 feet higher than the peak at WPS. The tunnel systems were completely full storing 1.4 BG (4,296 acre-feet) while reversals of 160 MG (491 acre-feet) and 400 MG (1,228 acre-feet) were made at WPS and CRCW, respectively.

h. Flood of September 2008. Record flooding occurred in and around the Chicago area and along the Illinois River from Dresden Island Lock and Dam down through La Salle, Illinois in response to heavy rainfall associated with the remnants of Hurricane Ike over a period from September 12-15, 2008. During the morning of September 13, the North Shore Channel rose 2.5 feet in approximately an hour and the Wilmette Pumping Station was opened to reverse flow into Lake Michigan followed by the CRCW. By 4 PM 4.71 inches of rain had fallen, with nearly 6 inches in the north basin, and the Thomas J. O'Brien Control Works were opened. After a lull during the evening of September 13th, rainfall resumed dumping an additional 2-2.5 inches of rain fell over the area, mainly Sunday morning. As a result, sector gates were opened at the Chicago and Thomas J. O'Brien Locks. The basin average storm total reported by MWRD was 6.83 inches and the Chicago O'Hare Airport station recorded a new daily record of 6.64 inches.

TARP, including the O'Hare Reservoir, was able to store and pump back approximately 3.0 BG (9,206 acre-feet) of combined sewer overflow to the WRPs during the event. The total reversal to Lake Michigan was 11.2 BG (34,371 acre-feet). An additional 1.5 BG (4,603 acre-feet) of water was diverted from the waterways outside of TARP by the Thornton Transitional Reservoir which is owned by the NRCS. The dewatering time was reported as 195 pump-hours, the longest to date. If all the reservoirs had been on-line the system might have been able to prevent much of the reversal as the total storage capacity will be 17.5 BG (53,705 acre-feet) when TARP is fully implemented. The total amount of stormwater that passed through the Lockport Powerhouse and Controlling Works was estimated at 59 BG (181,064 acre-feet) for the period September 12-17. The Lockport Powerhouse and Controlling Works operated at maximum capacity for 3.5 days continuously, at around 19,500 cfs.

i. Flood of July 2010. Light rainfall moved into the Chicago area during the evening of July 23, 2010 and 0.4 inches had fallen by midnight, with another 1-1.5 inches forecasted over the next 12 hours. Within two hours the forecast was upgraded to 3-4 inches, with 5-6 inches locally possible. By 1:50 AM, 1.92 inches had fallen in a 2-hour period resulting in reversals at the WPS and CRCW shortly thereafter. By 3:30 AM the Central basin had received 3.74 inches causing additional rises and the lock gates were fully open by 3:55 AM. At 6:40 AM the average rainfall for the waterways was 4.01 inches overall, with the Central basin reporting 5.63 inches, over 5 inches in a 6-hour period. The rains diminished through the remainder of the morning and ended before noon. Overall, the District received 4.69 inches, with storm totals for the North, Central, and South basins of 4.02, 6.23, and 4.03 inches, respectively. Approximately 750 MG (2,302 acre-feet) were released into the lake at the Wilmette Pumping Station, 1.5 BG (4,603 acre-feet) through the CRCW and another 4.3 BG (13,196 acre-feet) through the Chicago Harbor Lock. Local flooding was especially severe during this event, with many basements being flooded.

j. Flood of July 2011. Just three years after the previous rainfall record had been set, torrential rainfall fell over the Chicago area during July 23-24, 2011 with the Chicago O'Hare Airport reporting a record 6.86 inches on July 23. The rain fell in slightly over three hours exceeding the 100-year 3-hour storm by 2 inches. The average rainfall for the CAWS was 4.69 inches, with the Central area receiving 6.2 inches, and the North and South areas reporting around 4 inches. The heavy rain resulted in flow reversals at the WPS and CRCW of 750 MG (2,302 acre-feet) and 5.8 BG (17,800 acre-feet), respectively. The dewatering time for the Mainstream Tunnel system was reported as 130 pump-hours.

k. Flood of April 2013. On April 18-19, 2013 there was a significant rainfall event in northeastern Illinois resulting in high water levels and flooding throughout area waterways, including the Des Plaines River. Rainfall started overnight on April 17 and continued through April 18, with a total duration of 18-24 hours. Most of the area received 4 to 5 inches, with localized precipitation exceeding 7 inches. The Des Plaines and Fox Rivers reached major flood stage with record stages being reached at Des Plaines and Riverside for the Des Plaines River and Algonquin and McHenry for the Fox River. The event was relatively minor east of Cline Avenue on the Little Calumet River. Approximately 1.429 BG (4,385 acre-feet) were released into the lake at the Wilmette Pumping Station, 3.186 BG (9,774 acre-feet) through the O'Brien Lock, and 6.105 BG (18,731 acre-feet) through the CHL & CRCW.

l. Flood of June 2014. Beginning during rush hour of June 30th and continuing into the early morning hours of July 1st, two separate derechos moved through the Chicagoland area. Although these systems are primarily characterized by widespread, fast-moving, straight-line windstorms, they also brought torrential downpours. Most of the area received 2 to 3 inches, with the highest amounts of rainfall occurring in parts of Cook and DuPage Counties and Lake County in Indiana. Localized precipitation exceeded 4 inches in some locations. Midway reported rainfall reaching an intensity of 1.2 inches over 20 minutes. Localized flooding closed several major roadways and caused the Des Plaines River, Fox River, Little Calumet River, and North Branch of the Chicago River to approach flood stage. Approximately 163.0 MG (500.1 acre-feet) through the Wilmette Pumping Station and 362.0 MG (1,111 acre-feet) through the CHL & CRCW were released to the lake.

m. Flood of July 2017. Late on the evening of July 11th and into early July 12th, multiple thunderstorms moved across the northern portion of the District, resulting in, at some locations, total rainfall depths in excess of 100-year events. The Fox River and Des Plaines River exceeded record flood stages at Algonquin, Russell, Gurnee and Lincolnshire. Localized precipitation ranged from 4 to 7 inches in Lake County, IL and southern Wisconsin. Cook County received 1 to 4 inches. Standing water 2 to

6 inches deep was reported near Belmont Avenue and Lakeshore Drive in Chicago. Mundelein reported standing water 8 to 10 inches deep. Numerous roadways were impassable, and basements were flooded.

n. Flood of May 2020. On the afternoon and into late evening on May 17th, storms resulted in flash flooding throughout the Chicago Metropolitan Area. Most of the area received 3 to 5 inches of rainfall. O'Hare measured 3.11" of rainfall, which is the 5th wettest May calendar day ever recorded. On May 14th, 3.53" was measured. The total for this four-day stretch was 7.88", very near the historical record for the month of May. Localized flooding closed several major roadways. The Des Plaines River exceeded flood-level stages at Des Plaines and River Forest, and the North Branch of the Chicago River exceeded flood-level stages at Grant Ave in Chicago. The Little Calumet River approached flood-level stages. Approximately 848.1 (2603 acre-feet) MG through the Wilmette Pumping Station and 1731.6 MG (5,314 acre-feet) through the CHL & CRCW were released to the lake.

o. Flood of July 2022. During the overnight hours of July 22nd into July 23rd, thunderstorms developed across portions of northern Illinois. These initial thunderstorms re-developed continuously over the same areas for several hours, leading to significant flash flooding across parts of Lake County, Illinois. As these storms moved southeast, they dropped between 2 to over 6 inches of rain. The Waukegan Regional Airport measured 3.8" of rainfall in 4 hours.

p. Flood of July 2023. During the afternoon and evening of July 1st through July 2nd, a slow-moving low-pressure system moved across the Midwest, resulting in multiple extended rounds of torrential rainfall in and near Chicago on July 2nd, leading to flash flooding. Daily rainfall totals ranged between 3" to 7" with Chicago Midway Airport receiving 4.68", though a few localized rainfall totals greater than 8" were seen on the far west side of Chicago. The worst of the flooding occurred on the west and southwest sides of Chicago and in the near west and southwest suburbs. In response to increased stages on the CAWS, MWRDGC reversed flows at the Wilmette Pumping Station and Chicago Harbor Lock. Federal disaster declaration was also later issued for federal funding assistance in recovery efforts.

q. Flood of September 2023. A slow-moving system tracked across the Chicago metro on September 17th, producing isolated areas of locally heavy rainfall. A narrow corridor of very heavy rainfall over the near south suburbs of Chicago caused severe flash flooding in Calumet City and surrounding communities. Rainfall totals of 4" to 6" were observed in southern Cook County with the Little Calumet River gage at South Holland receiving 5.69" of rainfall, though radar estimates suggest higher rainfall totals of up to 9" fell in, and just northwest of, Calumet City. Federal disaster declaration was also issued for federal funding assistance in recovery efforts.

4-07. Runoff Characteristics.[1] The watershed is heavily urbanized and includes the

[1] The typical operating condition of the CHL and CRCW assumes a hydraulic gradient away from Lake Michigan (i.e. lake level elevation is greater than that of the Chicago River). Accordingly, "downstream" refers to the inland direction away from the structure. This convention is assumed in subsequent sections.

City of Chicago and over 100 additional municipalities. The population of the watershed is approximately 5.5 million people. The municipalities are served by combined and separate storm and sanitary sewers. The combined sewer area within the watershed is 310 square miles. Separate storm and sanitary systems were implemented for new development beginning in the 1930s, but the old combined systems stayed intact.

Through the implementation of the Chicago Tunnel and Reservoir Project (TARP), described in Chapter 3, most combined sewer overflows flow into the Deep Tunnel system instead of the canal system. The diverted water is stored until the storm ends, after which it will be pumped to a WRP.

4-08. Water Quality. The MWRD is responsible for monitoring the water quality of the waterways within its jurisdiction. The MWRD maintains a water quality database that goes back to 1970 and disseminates this information through their website. A map of the waterways, both natural and manmade, along with the location of the water quality monitoring stations is shown on Plate 4-2. The manmade water courses are: the North Shore Channel which connects Lake Michigan to Wilmette to the North Branch of the Chicago River, the CSSC which extends from the South Branch of the Chicago River near Damen Avenue to the Lockport Powerhouse, and the Calumet-Sag Channel which connects the Little Calumet River with the CSSC.

The natural rivers systems are the Chicago River System including the North Branch of the Chicago River, the Des Plaines River which joins the discharge from the CSSC downstream of the Lockport Powerhouse, and the Calumet River System, which flows into the Calumet-Sag Channel.

The North Shore Channel, the Chicago River, and the Calumet River generally have much higher water quality than the remainder of the Waterways System because these reaches are the first to receive the lake water withdrawn from Lake Michigan for discretionary purpose. There is a progressive deterioration in dissolved oxygen levels moving from the North and South Branches of the Chicago River downstream to the Sanitary and Ship Canal. The mean dissolved oxygen in the lower reaches of the Sanitary and Ship Canal and the Calumet-Sag Channel generally falls below the standards. The levels of ammonia nitrogen follow an opposite pattern, increasing in downstream reaches of the Canals. Other constituents such as fats, oils, greases, and metals are also detected in levels exceeding standards less often.

To improve the Water Quality of the Waterways System, the State of Illinois had authorized the MWRD to divert an average of 270 cfs (of the 3,200 cfs allocated under the Supreme Court Decree) from Lake Michigan per year. This amount has since been reduced to 220 cfs through 2030. This amount of diversion is for discretionary purposes and is withdrawn mostly during the period of June through October. It is expected that the Tunnel and Reservoir Plan, Phase I and Phase II will improve the water quality in the Sanitary and Ship Canal and will gradually alleviate the need to divert Lake Michigan water for discretionary purposes. Table 2-1 in the Chicago Harbor Lock Water Control Manual shows the amounts of Lake Michigan waters attributed to direct diversion during the period 2011-2020.

4-09. <u>Channel and Floodway Characteristics</u>. The Main Channel of the CSSC was initially designed for a peak flow rate of 10,000 cfs. Shortly after completion in 1900, hydraulic capacity tests performed in 1901 indicated that the flow capacity was between 14,000 and 16,000 cfs. On February 21st, 1997, however, a maximum discharge of 19,466 cfs was recorded at the Romeoville gage. The North Shore Channel, connecting Lake Michigan at the WPS with the North Branch of the Chicago River, was completed in 1910 with a channel capacity of around 1,000 cfs. The WPS controls lake diversion and flood relief when reversals to Lake Michigan are required. The Chicago River was widened in 1912 to increase channel conveyance and lower velocities. The CHL and CRCW were built in 1938 to control lake diversion and provide flood relief when reversals to Lake Michigan are required.

The Calumet-Sag Channel was completed in 1922 allowing the Calumet River system to reverse its flow away from Lake Michigan into the CSSC. The Blue Island Lock and Dam were later replaced by the Thomas J. O'Brien Lock and Controlling Works in 1965, directing flow from an additional 260 square miles of the Calumet River drainage area toward Lockport. By 1974 a construction project had widened the Cal-Sag Channel from an 80-foot width to a 225-foot width for a distance of 16 miles. In addition to improving navigation conditions, the increased cross-sectional area of the Cal-Sag Channel allows more water to pass into the CSSC without requiring a substantially increased hydraulic gradient.

4-10. <u>Upstream Structures</u>. The major water body immediately upstream of the T.J O'Brien Lock are Lake Michigan, upon which there are numerous significant structures. The closest of these include Calumet Harbor, Burnham Harbor, 31st Street Harbor, and water intake cribs some distance offshore. These structures have no direct impact upon the operation of the T.J. O'Brien Lock.

4-11. <u>Downstream Structures</u>. There are a number of structures located downstream of the Thomas J. O'Brien Lock and Controlling Works. The major structures include Lockport Lock and Dam. A complete description of each structure is given in Chapter 2. The locations of the structures are shown on Plate 2-1, and the owners, operating agencies, and regulating agencies are listed in Table 1-1. Additional downstream structures and the navigation limits of these structures are listed in the "Illinois Waterway Navigation Charts, 2013".

5-01. Hydrometeorological Stations

a. Facilities. The Water Control Section in Chicago District (LRC) operates and maintains hydrometeorological stations the T.J. O'Brien Lock and Dam. MWRD maintains a network of water level and precipitation gages that are used for the operation of CAWS which are given in tables 5-1 and 5- 2, respectively. In addition, the Illinois USGS operates several hydrometeorologic stations within CAWS that report on a real-time basis. All the data are compatible with MVR's Corps Water Management System (CWMS). Since the data is transmitted hourly it is available on a real time basis. The reliability of the data is very good. The data collection system is discussed in sections 5-04 and 5-05. Chapter 6 discusses use of data in hydrologic forecasting and Chapter 8 summarizes responsibilities of water control management.

b. Reporting. The Illinois USGS data, real-time and historical, is available through the National Water Information System (NWIS) at http://waterdata.usgs.gov/il/nwis/. Data from the hydrometeorological stations are stored in MVR's CWMS database. Gage height is converted to discharge in CWMS utilizing rating curves maintained by the USGS. Pool and tailwater readings at T.J. O'Brien Lock and Dam are manually entered into Lock Performance Monitoring System (LPMS) by Lock Personnel.

c. Maintenance. Gages within the MWRD operational network are maintained by MWRD personnel.

5-02. Water Quality Stations

a. Facilities. The Environmental Monitoring and Research Division of MWRD oversee the Ambient Water Quality Monitoring (AWQM) network associated with the CAWS. Grab samples are taken at 60 locations by MWRD personnel on a monthly basis. The samples are analyzed for 67 parameters using U.S. Environmental Protection Agency (USEPA) methods at MWRD laboratories. A map of the waterways service area and the sampling point locations is shown in Plate 4-2.

b. Reporting. Detailed annual water quality reports have been published by MWRD since 1972. Complete tabulations of water quality data collected by MWRD are available beginning in 1970. In addition, exceedances of water quality standards are reported quarterly. The Illinois National Environmental Protection Agency has also published annual summaries of its water quality database (STORET) since 1971.

c. Maintenance. The Metropolitan Water Reclamation District maintains the gages within their operational network.

5-03. Biological, Habitat, and Sediment Stations.

a. Facilities. In addition to the water quality parameters mentioned in Section 5-02, MWRD also monitors the stations within the network for biological, habitat, and sediment quality. The biological monitoring portion of the AWQM Program operates on a four-year cycle, with a focus each year on a different river system within CAWS. In addition, 15 stations are monitored on an annual basis on their proximity to water reclamation plants (WRPs) or municipal boundaries. Surface water grab samples are taken and analyzed at each station for chlorophyll along with samples for various chemical analyses.

Physical habitat assessment data sheets are filled out by MWRD biologists in the field at each location. Assessments made in the field include weather conditions, channel morphology, bank erosion, shore cover, aquatic vegetation, man-made structures, floatable materials, riparian land-use, sediment composition, sediment color and odor, depth of fine sediments (fines), and presence of oil in sediment which are based on field observations and analysis of grab samples. Fish are collected and analyzed by species, weight, length, and the incidence of disease, parasites, or other abnormalities. Sediment grab samples are analyzed for the presence of benthic invertebrates and sediment chemistry. Additional sediment samples are collected and analyzed for toxicity using the ten-day Chironomus tentans toxicity test.

b. Reporting. Detailed annual AWQM biological, habitat, and sediment reports have been published by MWRD since 2001. In addition, MWRD prepares four-year summary reports. The data are used to support Illinois Environmental Protection Agency (IEPA)'s efforts to make regulatory decisions, prepare 305 (b) reports in accordance with the Clean Water Act, and to prepare Use Attainability Analysis (UAA) for the components of the waterways.

c. Maintenance. The MWRD maintains the gages within their operational network.

5-04. Recording Hydrologic Data. Data collection platforms transmit data to the GOES-EAST satellite every hour on channels 49 and 177. The transmitted data is received at the Rock Island District office (MVR) via satellite and stored in LPMS, the CWMS database as well as the River gages database. A national continuity of operations plan/process (COOP) is also being implemented as a part of CWMS. The reliability of this system is increased by the following features at the MVR Headquarters: back up satellite dish, back up electrical power generator, and a secure and environmentally controlled computer room. Water Control personnel can view the database at the office or at home. MWRD collects elevation and precipitation data which is available upon request.

5-05. Communication Network. There are multiple paths for data transfer and communications. As discussed in 5-04, stage records and lockages are reported in LPMS. Direct communication with MWRD is provided through the telephone located in the Main Control Tower. The use of this phone is limited to the operation of the lock during storm backflow events. Personnel can also communicate with the Chicago District Office, the T.J. O'Brien Lock, MWRD, and other agencies through the internet via computer or by commercial phone.

5-06. <u>Communication with Project</u>. The Lock Performance Monitoring System (LPMS) and Lock Characteristics database provides Corps operators, planners, and managers with information on the use, performance, and characteristics of the Corps' national system of locks. The LPMS consists of data collected at Corps locks which is transmitted electronically to the central database which is managed by the Navigation and Civil Works Decision Support Center (NDC). The data includes the number of vessels and barges locked; type and dates of lockage's; durations of, and causes for, periods of lock unavailability; barge type, size, and commodity type; and tonnages carried. LPMS is accessed remotely by computers located at each lock and dam, various field offices, and Water Control personnel. Lock personnel enter vessel data for each lockage. The secondary communication network is via telephone. During emergencies, there are three means of communication available to lock and dam personnel:

a. Landline Telephone.
b. Cell phone.
c. E-mail.

Each morning at 0600, the Chief of Construction and Operations is provided with a situation report of the current status of the lock, focusing on whether there are currently any problems that prevent standard gate operations.

5-07. <u>Warnings</u>. The NWS Romeoville Forecast Office has the responsibility of issuing flood warnings including flash flood warnings in the Greater Chicago Metropolitan Area. When MWRD begins to draw down the pool in the CSSC, MWRD notifies lockmasters at Lockport Lock, Thomas J. O'Brien Lock and Controlling Works, and the CHL. In the event of an imminent backflow event LRC issues a Navigational Update. No other special procedures are followed at the Thomas J, O'Brien Lock.

HYDROLOGIC FORECASTS

6-01. General. Regulation of the Chicago Area Waterway System (CAWS) requires a thorough analysis of precedent and current weather and streamflow conditions and their projections into the future. The operation of CAWS is under the jurisdiction of the Metropolitan Water Reclamation District (MWRD). The Corps of Engineers and MWRD cooperate closely to maintain enough navigation depth throughout the canal system while also providing storage and conveyance for stormwater runoff. Hydrologic forecasting is an important component of the operation of CAWS.

a. Role of the Corps of Engineers. The Corps of Engineers exchanges data and cooperates with MWRD to facilitate hydrologic forecasting and operation of the canal system above Lockport. The Corps of Engineers, Chicago District (LRC) operates and maintains the T.J. O'Brien Lock and Controlling Works in conjunction with MWRD.

b. Role of the Metropolitan Water Reclamation District. MWRD is responsible for the operation of the canal system upstream of the Lockport Lock and Dam, in coordination with the Corps of Engineers. The project is operated to divert excess runoff and wastewater during extreme rain events down the Illinois Waterways away from Lake Michigan in so far as possible while maintaining a minimum nine-foot navigation project depth. In addition, MWRD diverts water from Lake Michigan to increase the dissolved oxygen (DO) levels within the canal system as specified in Section 7-03.

c. Role of Other Agencies. The National Weather Service (NWS) Forecast Office in Romeoville, Illinois, issues zone weather forecasts that cover time periods out to seven days, twice daily. NWS products are obtained via the Internet. The products provide adequate detail to alert the System Dispatcher and Chicago District (LRC) personnel of potential storms.

6-02. Weather Forecasts

a. Short-Range Forecasts. NWS forecast products are obtained by LRC via the Internet. The products provide adequate detail to alert the System Dispatcher and LRC personnel of potential storms.

b. Severe Storm Warnings. The Storm Prediction Center (SPC) at Norman, Oklahoma, is responsible for preparing and releasing products, in collaboration with local NWS offices, dealing with hazardous and severe weather including severe thunderstorms and tornadoes. The storm watches are issued when conditions are such that a severe storm could occur in an area and are distributed to the mass media by local NWS offices. When the SPC feels confident about the possibility of severe weather in a specific area, the watch is usually issued at least one hour prior to the onset of severe weather. Tornado and severe storm warnings are issued by the local NWS offices when a storm appears to be imminent as indicated by radar or identified by a storm-reporting observer. Storm watches and warnings are received are immediately viewable via the Internet. The location of the forecasted storm and an estimate of the expected rainfall are available when needed. The SPC also prepares forecasts of thunderstorm activity, both severe and non-severe, for days one and two.

c. Quantitative Precipitation Forecasts. The NWS Hydrometeorological Prediction Center (HPC) prepares five-day quantitative precipitation forecasts (QPFs). The term QPF is defined as the total amount of expected liquid precipitation forecasted for a given area. A QPF is specified when a measurable (>0.01”) precipitation type is forecast for any hour during a QPF valid period. The products are graphically displayed showing contours of various predicted rainfall amounts for a given area. HPC also analyzes an ensemble of forecast model products to derive a probability distribution about the HPC QPF which is in turn utilized to generate probabilistic forecasts of precipitation. QPFs for Days 1-3 are broken down into 6 and 24-hour increments and are sent out twice daily. A 48-hour QPF is issued twice daily for Days 4-5. The QPF products are received by the Hydraulic and Hydrologic Section via the Internet.

d. Flash Flood Guidance. Flash Flood Guidance is used to predict the occurrence of flash flooding in a specific area based on specified rainfall amounts within a given duration of time. The North Central River Forecast Center (NCRFC) calculates and issues products with guidance values for 1, 3, and 6-hour rainfall totals for all counties within the NCRFC region. The NWS WFO at Romeoville, Illinois uses this guidance when issuing flash flood watches and warning to the public within their service area including the Greater Chicago Metropolitan Area.

6-03. Operational Flood Forecasting MWRD utilizes a private meteorologic service to forecast precipitation in addition to the NWS and a precipitation network of 14 rain gages located throughout the Chicago area that they maintain. The data is readily available to the System Dispatcher at the operations center on a real-time basis. During significant storm the System Dispatcher contacts the NWS periodically. When severe storms are forecast, the dispatcher also double checks the opinions of the private meteorological service.

The following classification system is used by MWRD as a guide regarding forecasted/ongoing rain events.

1. Alert. An alert is issued when it is determined that precipitation may be coming into the area and is more than four hours away and the probability that a warning will be needed is less than 100%.
2. Advisory. An advisory is issued when a period of light rain, showers, or drizzle with accumulation amounts between a trace and 0.2” is expected in the immediate future.
3. Warning. A warning is issued when at least 0.2” per hour of rain, lasting several hours, is forecasted to occur within four hours of the issuance time.

The systems dispatcher also monitors radar imagery with respect to storm location, timing and intensity. The hydrometeorological observations are used to regulate the canal operation as detailed in Exhibit C.

WATER CONTROL PLAN

7-01. General Objectives. The primary object for water control is to limit the diversion of Lake Michigan waters into the Chicago Area Waterways (CAWS) while maintaining navigational water levels. In conjunction with the diversion, a secondary objective is the operation of lock and control structure in a way to provide a degree of flood control to alleviate flooding in the Chicago area below the facility.

During extreme rainfall events water may be discharged to Lake Michigan at five locations: the Wilmette Pumping Station (WPS), CHL & CRCW, the T. J. O'Brien Lock and Controlling Works, the 95th Street Pumping Station, and the 122nd Street Pumping Station. Discharging excess stormwaters to Lake Michigan minimizes potential for severe flooding along the CAWS. The Wilmette Pumping Station is used to regulate the stage in the North Shore Channel during extreme flood events, in addition to diverting water from Lake Michigan for water quality purposes. Adjacent to Navy Pier, the CHL and CRCW are used for navigation and to control the movement of water between Lake Michigan at the Chicago Harbor and the Chicago River, which is connected to the Illinois Waterway via the Chicago Sanitary and Ship Canal (CSSC). The Chicago Harbor Lock is operated by the U.S. Army Corps of Engineers, Chicago District (LRC) in cooperation with Metropolitan Water Reclamation District (MWRD), while the Controlling Works are operated by MWRD. The Thomas J. O'Brien Lock and Controlling Works are used to control the movement of water between Lake Michigan and the Calumet River, which connects to the Illinois Waterway through Lockport Lock, via the Calumet-Sag Channel and the Chicago Sanitary and Ship Canal while maintaining navigation. The lock is operated by the U.S. Army Corps of Engineers, Chicago District (LRC) while the controlling works are operated by LRC as instructed by MWRD. The canal system above Lockport may be used for limited flood control storage when its level is drawn down at the Lockport Powerhouse and Controlling Works prior to and during storm events.

7-02. Major Constraints. The normal elevation of the Lockport Pool is -2.0 feet Chicago City Datum (CCD) or 577.5 feet National Geodetic Vertical Datum (NGVD). The maximum pool elevation is +5.0 feet CCD (584.5 NGVD), although backflows at the CHL are initiated when the elevation reaches +3.5 CCD. The maximum head differential between the pool and lake level elevations is 5 feet.

The canal system downstream of the CHL and CRCW is drawn down to provide storage in preparation for and during storm runoff periods. The procedures used and the pertinent elevations are described in Chapter 3 of the MWRD System Dispatcher Manual. A quick overview of the manual is given below while a more detailed summary is included in Exhibit C. The minimum allowable Lockport Pool elevation during a drawdown event is -10.0 feet CCD (569.5 feet NGVD). This depth is required to provide clearance over the Lockport Lock upper gate. The minimum allowable elevation at the Calumet-Sag Junction is -4.0 feet CCD (575.5 feet NGVD) to maintain a 9-foot depth for navigation in the Calumet-Sag Channel. The maximum water level in the North Shore Channel is +5.0 feet CCD (584.5 NGVD). When this elevation is reached, flood water is released from the channel at the Wilmette Pumping Station into Lake Michigan at Wilmette Harbor. Discharge to Lake Michigan from the Chicago River Controlling Works and the Thomas J. O'Brien Lock and Controlling Works is allowed to maintain a maximum elevation of +3.5 feet CCD (583.0 NGVD). Table 7-1 lists the maximum recorded water levels on the canal system and the date of occurrence.

Table 7-1 Record High Stages on the CAWS

River or Channel	Location	Stage (CCD)	Date
North Shore Channel	Wilmette Pumping Station	+ 9.90	7/12/1957
Chicago River	Chicago River Controlling Works	+ 4.35	5/17/2020
Chicago Sanitary and Ship Canal	Cal-Sag Junction	+ 2.80	5/17/2020
Chicago Sanitary and Ship Canal	Thomas J. O'Brien Controlling Works	+ 4.30	7/18/1996

7-03. Overall Plan for Water Control. The T.J. O'Brien Lock and Controlling Works are two of the nine navigation structures on the Illinois Waterway which operate as a system to provide 9 feet of navigation depth over a distance of 327 miles from the confluence with the Mississippi River at Grafton, Illinois to Lake Michigan at Calumet Harbor. The CSSC also provides a connection to Lake Michigan at Chicago Harbor via the Chicago Harbor Lock and Controlling Works.

a. water supply taken from various intake points and discharged into the CAWS as WRP effluent and occasional combined sewer overflows.

b. storm runoff discharged from the diverted watershed area of Lake Michigan, draining to the river and canal system in the greater Chicago area.

c. water from Lake Michigan entering directly into the river and canal system in the greater Chicago area, consisting of:

    1. Water required for lockage at the Chicago and Thomas J. O'Brien Lock

    2. Leakages occurring at the CHL and CRCW and turning basin walls (Chicago Harbor), Thomas J. O'Brien Lock and Dam, and Wilmette Pumping Station

    3. Direct diversions for navigational make-up and discretionary (water quality improvement) purposes made at the Chicago River Controlling Works and Thomas J. O'Brien Controlling Works, and discretionary purposes at the Wilmette Pumping Station.

7-04. Standing Instructions to Lockmaster. The Lockmasters at the T.J. O'Brien Lock and Controlling Works is furnished with instructions that outline the steps to be taken by the Lockmaster for collecting and transmitting hydrometeorological data and reading and recording of all gages and gate settings when communication with the Chicago District Office is interrupted. The Lockmaster at T.J. O'Brien Lock and Dam is responsible for the operation of the sluice gates at the Controlling Works as directed by System Dispatcher at MWRD. These instructions are listed in Exhibit D of this manual.

7-05. Procedures During Flood Forecasts. When a storm warning/advisory/alert is issued, and there is a forecast for a 50% or more chance of rain, the inflow through the Wilmette sluice gates is stopped. MWRD increases the discharge at the Lockport Powerhouse prior to the start of the storm. Increasing the discharge causes the water level in the Chicago Sanitary and Ship Canal at the Lockport Powerhouse to decrease to as low as elevation -10.0 CCD (569.5 NGVD). The amount of this decrease is dependent upon the severity of the predicted storm as well as upstream constraints. In severe storms water is also discharged at the Lockport Controlling Works. This reduced water level increases conveyance in the canal and river system by establishing hydraulic gradient towards the Lockport Lock, Powerhouse, and Controlling Works. It also provides up to an additional 749 MG (2,300 acre-feet) of flood storage capacity in the upstream waterways. The waterway is normally operated at virtually a flat hydraulic gradient. Because it generally takes five hours for a gate operation to establish an efficient upstream flow pattern, the gate operation must be made well in advance of the storm to minimize upstream water level increases.

The elevation at the Chicago Harbor Lock and Chicago River Controlling Works and O'Brien Lock and Controlling Works is generally held to -2.0 feet CCD (577.5 feet NGVD) by adjusting sluice gate openings at these locations. As stages increase in the Chicago River, lockage operations are stopped at the Chicago Harbor Lock and both west sector gates are opened. In the event power to the gates is lost (whether through total power loss on site or through flooding of the mechanical pit), the gates must be operated manually. By opening the west gates early, it is only necessary to open one set of gates to initiate a backflow rather than two. If the average elevation at either location rises above -2.0 feet CCD (577.5 feet NGVD), the sluice gates at that location are shut immediately to hold the level at -2.0 feet CCD (577.5 feet NGVD) as long as possible. The passing of Lake Michigan water through the sluice gates to maintain minimum canal water elevation is called navigation makeup diversion. When it is raining, discretionary diversion of water from Lake Michigan is typically stopped at both locations.

The Chicago River Controlling Works and the Thomas J. O'Brien Controlling Works are opened to allow stormwater to flow into Lake Michigan when the river levels reach +3.0 feet CCD (582.5 feet NGVD) and there is any indication that the river will continue to rise with the possibility of exceeding +3.5 feet CCD (583.0 feet NGVD). Sector gates are opened up as a last resort at the Chicago Harbor Lock and Thomas J. O'Brien Lock. In the event of the Chicago River reaching +3.5 feet CCD (the bottom of the machinery pits where the gate operating mechanisms are housed) and no notification has been received by MWRD, Corps personnel should contact the MWRD Systems Dispatcher to determine if a backflow event should be initiated. If significant precipitation is not occurring and water levels are rising slowly, the discharge to the lake should be held until the level reaches +3.5 feet CCD (583.0 feet NGVD). Discharge to the lake through the Wilmette Pumping Station occurs when the elevation of the North Shore Channel reaches +4.5 CCD (584.0 NGVD) and there is any indication that the river will continue to rise with the possibility of exceeding +5.0 feet CCD (584.5 feet NGVD). High flow conditions during the drawdown at Lockport increases the risk of barges breaking loose which may lead to temporary closure of the river at the discretion of the Lockmaster. Backflows to Lake Michigan since 1985 are shown in Plate 4-1.

7-06. Organization of Water Control

a. Regulation. The canal system downstream of the Chicago Harbor Lock and Chicago River Controlling Works is regulated by the MWRD in cooperation with the Chicago District, U.S. Army Corps of Engineers.

b. Lockmaster. Field operation of the T.J O'Brien Lock is under the jurisdiction of the respective Lockmaster.

c. U.S. Army Corps Personnel at Chicago Harbor Lock. The Chicago District provides personnel at the T.J. O'Brien Controlling Works as directed by the MWRD Systems Dispatcher.

d. MWRD Personnel at Control Structures. The MWRD maintains personnel at the Lockport Controlling Works during storm events. Wilmette Pump Station and Lockport Powerhouse are operated remotely from the MWRD Waterway Control Center (WCC). The Lockport Powerhouse, however, is also staffed during working hours. The sluice gates at the CRCW are remotely controlled from the MWRD Waterway Control Center.

e. MWRD Waterway Control Center. Field operation of MWRD structures is coordinated through its Waterways Control Center located at 100 East Erie Street, Chicago, Illinois. MWRD project and field personnel receive instructions on canal operation from the Systems Dispatcher. MWRD controls canal elevations by allowing certain discharges to pass through the Lockport Powerhouse, Lockport Controlling Works, Thomas J. O'Brien Controlling Works, Chicago River Controlling Works, and the Wilmette Pumping Station. In addition, sector gates are opened up as needed at the Chicago Harbor Lock and Thomas J. O'Brien Lock during flow reversals associated with extreme storm events.

f. Public Relations. Periodically, it is necessary to keep the public interests, which are directly affected by the operation of the Chicago Harbor Lock and Chicago River Controlling Works, informed of the operation, or expected flow conditions in the waterway. The Public Affairs Office of the Chicago District issues information releases on lock operation to the news media for public dissemination. The basic information for the news releases is provided by the Operations Section and the Illinois Waterway Project Office.

g. Emergency Conditions. An "emergency" is considered to exist when computer, telephone, or radio communications cannot be established between the Lockmaster and the home office, or between the U.S. Army Corps of Engineers and MWRD. During such situations, the operation of the lock will be administered in accordance with provisions contained in the Standing Instructions listed in Exhibit D of this manual.

Other emergency conditions can exist which may pose a significant hazard to life and/or property. These conditions may include embankment failure, extreme storms, excess seepage, sabotage, dam failure, and lock gate failure. During these situations, the operation of the Lockport Lock and Dam, the Lockport Controlling Works, and the Chicago Sanitary and Ship Canal retaining walls will be administered in accordance with provisions contained in the U.S. Army Corps of Engineers publication, "The corresponding publication for the T.J. O'Brien Lock and Controlling Works is the updated "Emergency Action Plan, T.J. O'Brien Lock and Controlling Works,".

7-07. Deviation from Normal Regulation. LRC is occasionally requested to deviate from normal regulation of the pool. Prior approval for a deviation is obtained from the Lakes and Rivers Division (LRD), except as noted in subparagraph (a) below. Deviation requests should be coordinated with the Mississippi Valley Division (MVD) when impacts of the deviation could affect areas of concern within MVD's jurisdiction. Deviation requests usually fall into the following categories.

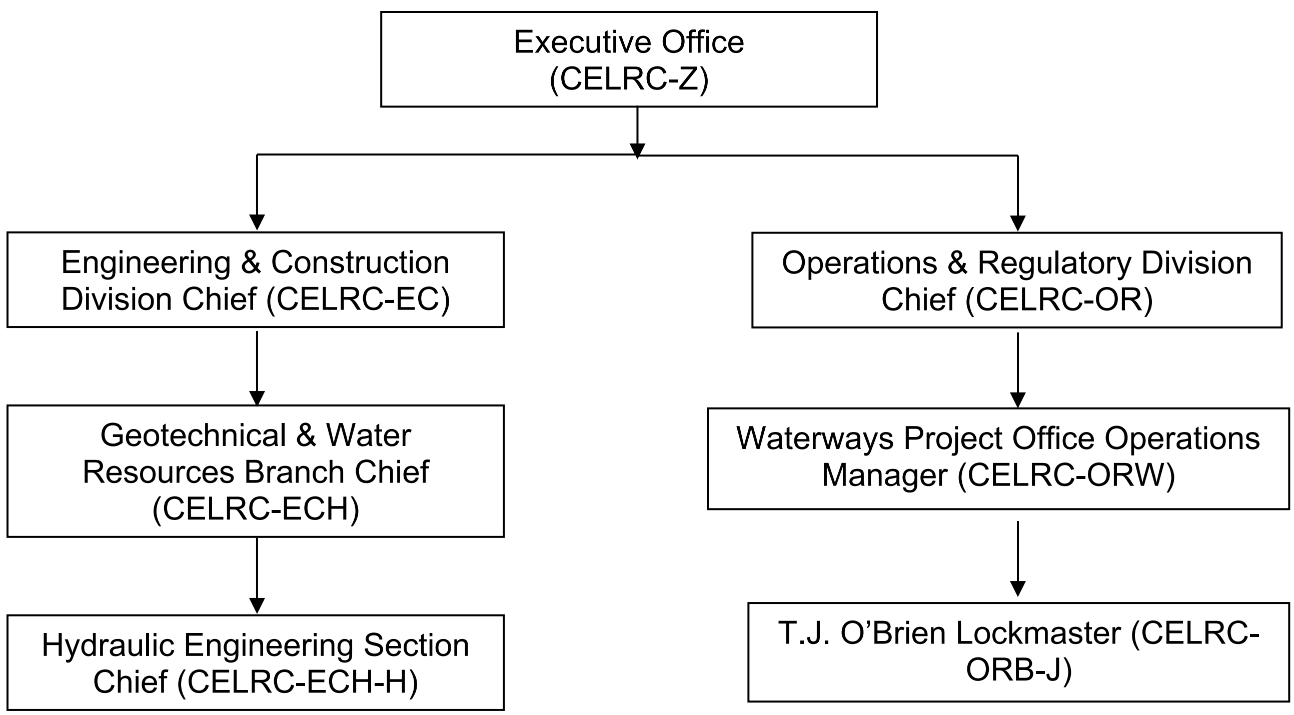
a. Emergencies. Some emergencies such as drowning, towboat and other accidents, failure of operation facilities, towboat accidents, or possible chemical and oil spills require water control actions to be taken immediately unless such action would create equal or worse conditions. The Lakes and River Division is informed as soon as possible. A written description of the deviation, how long it was or will be in effect, and the reason it was needed should be sent to the Division Water Control Manager.

b. Unplanned Minor Deviations. There are unplanned instances that create a temporary need for minor deviations from the normal facility operations, although they are not considered emergencies. Changes in operations are sometimes necessary for maintenance and inspection. Requests for changes in operations are generally for a few hours to a few days. Each request is analyzed on its own merits. Consideration is given to potential flood threat and possible alternative measures. In the interest of maintaining good public relations, the requests are complied with, providing there are not adverse effects on the overall regulation of the project for the authorized purposes. Under the provisions of paragraph 3-4d of ER 1110-2-240, within 30 calendar days of commencing the deviation, the District Commander or designee shall submit a record of deviation.

c. Planned Deviations. Each condition should be analyzed for its merits. Sufficient data on flood potential and watershed conditions, possible alternative measures, benefits to be expected, and probable effects on other authorized and useful purposes will be presented by letter, telephone, or e-mail to the Lakes and River Division along with recommendations for review and approval.

8-01. <u>Responsibilities and Organization.</u> As owner, the US Army Corps of Engineers has direct responsibility for all project purposes. Direct responsibility for regulation of the T.J. O'Brien rests with the Chicago District Engineer. Planning and administration of lock and dam regulation is assigned to the Hydraulic Engineering Section, Geotechnical & Water Resources Branch, Engineering & Construction Division. Operation and maintenance of the T.J. O'Brien projects is assigned to the Operations & Regulatory Division and lock personnel. The Lockmaster at T.J. O'Brien can be reached at [redacted]. Figure 8-1 shows the district organization concerning lock and dam regulation.

Figure 8-1 Organization of Lock Operation within Chicago District



During extreme flood events, when flow reversal into Lake Michigan becomes necessary, MWRD issues gate settings for the T.J. O'Brien Control Works to the Lockmaster or his staff. The T.J. O'Brien Lock are attended 24 hours a day, seven days a week by MVR Personnel. If MWRD cannot contact Lockport then Brandon Road will be directed to contact Lockport personnel by Marine Radio, if necessary, to pass along the information and to call MWRD to verify message receipt. Also, the Lockmaster or any of his staff may contact the Water Control Section duty forecaster at any time when necessary. The duty forecaster's cell phone number is [redacted].

Corps of Engineers personnel performs all routine operation and maintenance for the project, as outlined in the Master Water Control Manual. Standing Instructions to the Lockmaster are outlined in Exhibit D of this manual. The standing instructions outline the steps to be taken by the Lockmaster for collecting and transmitting hydrologic data, including reading and recording of gages and gate settings on the dam when communication with the District office is disrupted. Coordination with other agencies concerning the water control plan is outlined in Chapter 5 and Paragraph 8-02. Any deviation from the authorized Water Control Plan must be approved by the U.S. Army Corps of Engineers, Great Lakes and Ohio River Division office (LRD), Cincinnati, Ohio.

8-02. Interagency Coordination

a. Local Press and Corps Bulletin. Periodically it is necessary to keep local interests affected by unusual operations and important events regarding the operation and regulation of the T.J. O'Brien Lock and Controlling Works. The Public Affairs Office, Chicago District, is responsible for issuing information releases to the local news media for public dissemination.

b. U.S. Geological Survey. The U.S. Geological Survey (USGS) measures and reports the flows and stages at several gage stations including the CSSC near Lemont and Chicago River and Lake Michigan at CRCW. Gage data is obtained by the Hydraulics and Hydrology Section using the USGS website. Operation and maintenance of the gages is performed under a cooperative agreement between the U.S. Army Corps of Engineers and the USGS.

c. Metropolitan Water Reclamation District. The MWRD and the Corps of Engineers coordinate activities in connection with the operation and regulation of the canal system to minimize flooding while maintaining navigation.

d. Port of Chicago. The Corps and the Port Authority have reciprocal duties with reference to incoming and outgoing freighters and other large vessels. The Corps will inform the Port Authority of any major shutdown of Gate operation or major traffic problems occurring in the lock adjacent areas. The Port Authority informs the Corps of incoming vessels.

e. Other Local, State and Federal Agencies. In times of emergency, the Illinois Emergency Management Administration is notified. When reversals occur, MWRD notifies Cook County, the Illinois and U.S. EPA, National Response Center, City of Chicago Mayor's office, in addition to others listed in Form 4.2 Reversals to Lake Michigan Notification List, System Dispatcher Manual. In addition, when drawdowns occur, MWRD notifies the Lockport and Brandon Road Locks, U.S. Coast Guard, in addition to several local public and commercial entities as listed in Form 4.1 Lockport Powerhouse Canal Drawdown Call Out Record in the MWRD Systems Dispatcher Manual.

8-03. Interagency Agreements. The Corps of Engineers and the MWRD have entered into several agreements concerning operation of the structures and canal system from

Lockport Lock and Dam upstream. The first agreement, attached as Exhibit E, discusses the operation of the T.J. O'Brien Lock by the Corps of Engineers.
A 1984 Memorandum of Agreement between the Department of the Army and MWRD discussing operation and maintenance of CAWS including the Chicago Harbor Lock and Chicago River Controlling Works, the Lockport Controlling Works, the Lockport Dam and Powerhouse, and the canal banks, levees, and retaining walls is attached as Exhibit F.

8-04. Continuing Studies

a. Lake Michigan Diversion. Lake Michigan Diversion annual reports are prepared as part of the Corps of Engineers role in monitoring the diversion of water from Lake Michigan at Chicago. Until 1987, the Chicago District had a supervisory role in the accounting procedures, data recording, and periodic investigation and calibration of the measuring devices. Every five years, the Chicago District convenes a three-member technical committee to determine the best current engineering practice and scientific knowledge for measuring and computing diversions.

b. Tunnel and Reservoir Plan. The Tunnel and Reservoir Plan (TARP) described in Chapter 3 is currently being implemented by MWRD. The operation of the canal system will have to be re-evaluated as the TARP reservoirs are completed and come online. The Chicago District is investigating alternative models to replace the existing TNET model used to model the TARP system.

c. Monitoring and Rapid Response Plan for Invasive Carp. The overall goal is to prevent invasive carp from establishing self-sustaining populations in the Chicago Area Waterway System (CAWS) and Lake Michigan. Five strategic objectives have been identified to accomplish the overall goal. These objectives are: Determine the distribution and abundance of any invasive carp in the CAWS, and use this information to initiate rapid response removal actions; Remove any invasive carp in the CAWS to the maximum extent practicable; Identify, assess, and react to any vulnerability in the current system of barriers to prevent invasive carp from moving into the CAWS; Determine the leading edge of major invasive carp populations and reproductive success of those populations; and Improve understanding of the likelihood that invasive carp could become established in the Great Lakes.

In 2010, the U.S. Army Corps of Engineers designed and constructed the Des Plaines River barricade addressing the risk of invasive species bypassing the electrical barriers during extreme flood events into the Chicago Sanitary and Ship Canal (CSSC). The barricade was funded through the U.S. Environmental Protection Agency (EPA) as part of the Great Lakes Restoration Initiative in 2009. The Des Plaines River barricade consists of concrete barriers and a specially fabricated wire mesh that allows water to flow through the fence while preventing the passage of fish. The fence extends approximately 13 miles from Romeoville, Illinois to Willow Springs, Illinois.

d. Great Lakes and Mississippi River Interbasin Study. The U.S. Army Corps of Engineers, in consultation with other federal agencies, Native American tribes, state agencies, local governments, and non-governmental organizations, is conducting the Great Lakes and Mississippi River Interbasin Study (GLMRIS) pursuant to Section 3061(d) of Water Resources Development Act of 2007. The study evaluated a range of options aimed at preventing, including the reduction of the risk to the maximum extent possible, the spread of aquatic nuisance species between the Great Lakes and Mississippi River Basins through the CSSC and other aquatic pathways. The report was published in January 2014.

e. Updated Water Use Designations. In conjunction with the Illinois EPA, MWRD is studying alternatives to meet the new dissolved oxygen standards required under the newly established water use designations within CAWS as discussed in Section 3-07.

f. Periodic Inspection Reports. Periodic inspection reports are written by the Corps of Engineers on the condition of the CHL as part of the National Dam Safety Program. Generally, these inspections are made at approximate five-year intervals depending upon the condition of the structure and the results of the previous inspections. Representatives of the Chicago District will conduct the inspections. Each inspection will review the structural integrity of the lock and the condition of its mechanical and electrical systems. A written report of each inspection will be prepared by the Corps and kept on file at the Chicago District office.

g. CRCW Discharge Rating Curves. The University of Illinois at Urbana-Champaign completed a study in July 2014 which primary objective was to develop discharge rating curves for the sluice gates and navigational lock at the CHL and CRCW during the backflow operation. A copy of the July 2014 report is attached as Exhibit G.

Table 2-1 Public Facilities along the Chicago Area Waterway and Related Waterways[1]

Watershed and Name	Civil Division	Location
Chicago Sanitary and Ship Canal		
- Forest Preserve District of Cook County (Palos Preserves)	Towns of Lemont, Lyons and Palos	Upstream of Cal-Sag Junction
South Branch Chicago River		
-None		
North Branch Chicago River		
- Horner Park	City of Chicago	
- River Park (East and West)	City of Chicago	Confluence of NB Chicago River and North Shore Channel
North Shore Channel		
- Legion Park No. 2	City of Chicago	
- Ladd Arboretum	City of Evanston	
- Sheridan Shore Yacht Club	Village of Wilmette	North Shore Channel at Lake Michigan
Chicago River		
- None		
Calumet-Sag Channel		
- Forest Preserve District of Cook County (Palos Preserves)	Towns of Lemont and Palos	Upstream of Cal-Sag Junction
- Worth Municipal Boat Ramp	Village of Alsip	River Mile 311.3
- Howe's Landing Boat Ramp	Village of Worth	River Mile 313.8
Little Calumet River		
- Forest Preserve District of Cook County (Beaubien Woods)	City of Chicago	River Mile 324.0
- Forest Preserve District of Cook County (Whistler Woods)	Village of Riverdale	River Mile 320.3
- Forest Preserve Distrit of Cook County (Calumet Woods)	Village of Riverdale	Upstream of Confluence with Cal-Sag Channel and Hwy 57
Calumet River		
- None		

Table 2-1 Public Facilities along the Chicago Area Waterway Downstream of the Chicago Harbor Lock and Chicago River Controlling Works[1]

Watershed and Name	Civil Division	Location
Des Plaines River		
- Forest Preserve District of Cook County (Lockport Prairie Nature Preserve)	Village of Lockport	Upstream of Lockport Lock and Dam
- Forest Preserve District of Cook County (Isle A LeCache)	Village of Romeoville	River Mile 293.1 Upstream of Lockport Controlling Works
- Forest Preserve District of Cook County (Romeoville Prairie Nature Preserve)	Village of Romeoville	
- Forest Preserve District of Will County (Keepataw Preserve)	Village of Lemont	
- Forest Preserve District of Cook County (Black Partridge)	Village of Lemont	River Mile 299.5
- Forest Preserve District of Du Page County (Waterfall Glen)	City of Darien	River Mile 301.0 East of Lemont Road
- Forest Preserve District of Will County (Columbia Woods)	Village of Willow Springs	River Mile 307.0 Upstream of Cal-Sag Junction
- Forest Preserve District of Cook County (Portage Woods)	Village of Lyons	River Mile 313.9 West of Hwy 43

Table 5-1 MWRD Water Level Gage Network

Elevation Gages North Area

1N	Wilmette Lake	N. of WPS (Canal Wall) 613 Sheridan Road
2N	Wilmette Pump Station	S. of WPS (Canal Wall) 613 Sheridan Road
3N	North Branch Chicago River - Albany	NB Chicago River (SE corner of Albany & bridge)
4N	North Branch Chicago River - Lawrenc	North Branch Pump Station

Elevation Gages Central Area

1C	CRCW - Lake	CRCW Operators House. 1st Gate - 108 Streete
2C	CRCW - River	CRCW Operators House. A
3C	31st & Western	RM 320.5 on CSSC
4C	Willow Springs	RM 307.8 on CSSC
5C	Des Plaines River - Lockport	
6C	Main Channel - Lockport	Main Channel - Controlling Works
7C	Lockport - Canal West	LPH headrace, RM 291.1 on CSSC
8C	Lockport - Penstock	2 Head water level gages, RM 291.1 on CSSC
9C	Lockport - Tail Race	2 Tail water level gages, RM 291.1 on CSSC

Elevation Gages South Area

1S	T.J. O'Brien Upper Pool	134th St. & Calumet River N.
2S	T.J. O'Brien Lower Pool	134th St. & Calumet River S.
3S	SEPA 5 - Sag Junction	Rt. 83 & near Grant Rd.
4S	Cal-Sag Channel - SEPA 4	11531 South Harlem

List of Staff Gages - Manually Read

Location
Wilmette - Lake
Wilmette - Channel
CRCW - Lake
CRCW - Channel
T.J. O'Brien - Lake

Location
T.J. O'Brien - Channel
Sag Junction
Lockport Controlling Works - Canal
Lockport Headrace
Lockport Tailrace

Table 5-2 MWRD Precipitation Gage Network

Precipitation Gages North

1N	Chicago (North Branch PS)	4840 N. Francisco Avenue
2N	Skokie (NS WRP)	3500 Howard Street
3N	Wilmette	613 Sheridan Road
4N	Glenview	1333 Shermer Road
5N	Des Plaines (Kirie WRP)	701 West Oakton
6N	Hanover Park WRP	1200 E. Sycamore Ave.: Elgin & Barrington Roads

Precipitation Gages Central

1C	Chicago	100 East Erie Street
2C	Chicago (Racine Ave. PS)	3838 South Racine
3C	Cicero (SWRP)	6001 W. Pershing Road
4C	Chicago (Springfield Ave. PS)	1747 N. Springfield Avenue

Precipitation Gages South

1S	Chicago (87th & Western)	8659 S. Western Avenue
2S	Chicago (Melvina Ditch)	8644 South Natchez Avenue (Burbank)
3S	Chicago (Calumet WRP)	400 East 130th Street
4S	Chicago (95th St. PS)	9525 South Baltimore
5S	Lemont WRP	Stephen & River Street

SUPPLMEMTARY PERTINENT DATA

EXHIBIT A

GENERAL INFORMATION

Name of project	T.J O'Brien Lock and Controlling Works
Location	Calumet River-River Mile 326.0
Objective of Regulation	Navigation, power generation, flood control
Owner/Operator	U. S Army Corps of Engineers
Maximum Lift	5.0 feet
Upper and Lower Gates	Sector- type Sluice Gates at Controlling Works
Number	4
Dimensions (each gate)	10-foot square
Sill elevation	562.5 feet NGVD, - 17.0 Feet CCD

DATUMS CONVERSIONS

Chicago City Datum (CCD)	0.00 feet CCD = 579.48 feet NGVD29
1912 Adjustment (MSL 1912)	0.50 feet MSL 1912 = 0.00 feet NGVD29
International Great Lakes Datum (IGLD)	0.00 feet IGLD = 1.30 feet NGVD29
Lake Michigan Low Water Datum (LWD)	0.00 feet LWD = 578.10 feet NGVD29
CHL & CRCW	0.00 feet NGVD29 = -0.29 feet NAVD88
Lockport Lock	0.00 feet NGVD29 = -0.30 feet NAVD88
Thomas J. O'Brien Lock	0.00 feet NGVD29 = -0.34 feet NAVD88

LOCKPORT LOCK

Location	Illinois Waterway, Chicago Sanitary and Ship Canal River Mile 291.0
Project owner	U.S. Army Corps of Engineers (USACE)
Operating agency	USACE – Chicago District
Annual operation period	All Year
Lock dimensions	110 feet wide x 600 feet long
Maximum lift	42.0 feet
Average lift	38.0 feet
Upper guard gate	
Type	Submersible vertical lift
Dimensions	118feet wide x 24feet high
Upper service gate	
Type	Submersible vertical lift
Dimensions	118feet wide x 24feet high
Lower service gates	
Type	Miter
Dimensions (each leaf)	65 feet wide x 65 feet high
Elevations	
Upper gate sill:	
Guard gate	557.5 feet NGVD, -22.00 feet CCD
Service gate	557.5 feet NGVD, -22.00 feet
CCD Lower gate sill	523.5 feet NGVD, -5.6 feet CCD
Top of lock chamber	584.5 feet NGVD, +5.00feet CCD
Chamber floor	522.5feet NGVD, -57.00 feet CCD
Upper guide wall	584.5feet NGVD, +5.00 feet CCD
Lower guide wall	546.5feet NGVD, -33.00 feet CCD
Filling and emptying tunnels	2 – 12-foot Diameter

LOCKPORT POWERHOUSE

Location	Chicago Sanitary and Ship Canal West of the MWRD Lock
Owner/Operator	Metropolitan Water Reclamation District
Controlling Agency	Metropolitan Water Reclamation
District Generators	
Number	2
Type	Vertical Smith-Kaplan Variable Pitch Hydroelectric
Rating	6,500 kVa each
Operation	During dry weather, one generator runs at partial capacity. During rainstorms, both generators operated and often one or more sluice gates opened.
Turbines	
Number	2
Type	Vertical with variable pitch propellers
Rated horsepower	8,500 @ 37.5feet of head
Discharge rate	2,160 cfs
Operating hours	7 Days/Week-24 hours/day

LOCKPORT CONTROLLING WORKS

Location	Chicago Sanitary and Ship Canal River Mile 293.2
Owner/Operator	Metropolitan Water Reclamation District
Description	570 feet long structure with 15 bays of which 8 have been permanently bulkheaded and 7 contain 30feet wide x 20feet high vertical lift sluice gates
Elevations	
Gate sill	564.5feet NGVD, -15.0feet CCD
Lower floor	563.4feet NGVD, -16.1feet CCD
Outlet channel	562.4feet NGVD, -17.1feet CCD

WEST OR RIGHT EMBANKMENT

Location	Illinois Waterway River Mile 291.15 to 292.17
Type	Earth and rubble fill construction with 4,300-foot concrete cutoff wall (2009)
Length	1.02 miles
Top Width	32.85 feet
Slope (both land and canal sides)	1:1
Elevation, top	584.5feet NGVD, +5.0 feet CCD
Protective riprap, thickness:	2.0 feet, 2.0 feet
Location	Illinois Waterway River Mi1e 292.17 to 292.74
Type	Rock and rubble with earth core and with earthen levee
Length	0.57 miles
Top width	50.0 feet
Slope (both land and canal sides)	1:1
Elevation, top	584.5feet NGVD, +5.0feet CCD
Location	Illinois Waterway River Mile 292.74 to 293.09
Description	Rock and rubble with earth core
Type	0.35 miles
Length	50.0 feet
Top width	1:1
Slope (both land and canal sides)	584.5feet NGVD, +5.0feet CCD
Elevation, top	

EAST OR LEFT BANK RETAINING WALL

Location	Illinois Waterway River Mile 291.15 to 292.17
Type	Anchored concrete panel retaining wall with earth fill and rubble
Length	1.02 Miles
Top width	50 feet
Slope, outside	1:1
Elevation, top	584.5feet NGVD, +5.0feet CCD

WILMETTE PUMPING STATION

Location	North Shore Channel, River Mile 341.0
Owner/Operator	Metropolitan Water Reclamation District
Description	86 feet long structure consisting of a pumping station with 2 pumps, 2 tunnel gates, and 3 sluice gates.
Pump	
Number	2
Type	Propeller pumps
Capacity	1st: 250 cfs, 3 feet of head 2nd: 150 cfs, 3 feet of head
Sluice Gate Dimensions	2 tunnel gates 10ft (w) x 10 ft (h) 3 diversion/reversal gates 10ft (w) x 16 ft (h)

CHICAGO RIVER LOCK

Location	Chicago River - River Mile 327.0
Owner District	Metropolitan Water Reclamation
Operator	Chicago District, U.S. Army Corps of Engineer
Description	The controlling works consist of two sets of 4 sluice gates, one set located adjacent to, and north of, the river side gates of the lock and the other set on a segment of the south basin wall
Sluice Gates	
Number	8
Dimensions (each gate)	10-foot square
Sill elevation	561.5feet NGVD, -18.0feet CCD

CHICAGO RIVER CONTROLLING WORKS

Location	Chicago River - River Mile 327.0
Owner District	U.S. Army Corps of Engineers
Operator	Chicago District, U.S. Army Corp of Engineer
Description	The controlling works consist of two sets of 4 sluice gates, one set located adjacent to, and north of, the river side gates of the lock and the other set on a segment of the south basin wall.
Sluice Gates	
Number	8
Dimensions (each gate)	10-foot square
Sill elevation	561.5feet NGVD, -18.0feet CCD

AUTHORITIES AND DISCRETION CONCERNING OPERATION OF CHICAGO AREA WATERWAY SYSTEM

EXHIBIT B

DEPARTMENT OF THE ARMY
CHICAGO DISTRICT, U.S. ARMY CORPS OF ENGINEERS
111 NORTH CANAL STREET
CHICAGO IL 60606-7206

REPLY TO
ATTENTION OF:
CELRC-OC 25 March 2013

MEMORANDUM FOR CELRC-OC Attn: Kim Sabo

SUBJECT: Authority and discretion concerning operation of Chicago Area Waterway System

1. References are provided in a separate appendix.

2. You asked me to consider the extent of the Corps's authority to modify operations at the Chicago Harbor Lock, considering the statutory command to sustain through navigation.

3. The history of federal involvement in the Chicago Area Waterway System goes back nearly two centuries. This memorandum summarizes the variety of authorities that govern the Corps's activities with respect to the CAWS.

4. Summary

The Corps's authority over the Chicago Area Waterway System derives from the U.S. Constitution, federal statutes and regulations, and agreements with the Metropolitan Water Reclamation District. Though the Corps remains primarily responsible for navigation, the agency operates the waterway (and its locks) in coordination with MWRD to preserve water quality, regulate diversion from Lake Michigan, and protect the region against flood risks. The Corps ultimately retains a great deal of discretion to operate the waterway to balance these various purposes, subject only to the congressional command to sustain through navigation.

5. Background

The Supreme Court comprehensively documented the early history of a water-based connection between Lake Michigan and the Illinois River, noting that federal involvement in the project began as early as 1822. *See Wisconsin v. Illinois*, 278 U.S. 367, 401-07 (1929). The Chicago Sanitary and Ship Canal was opened in January 1900 for the purpose of conveying sewage away from Lake Michigan, Chicago's drinking water source. *Id.* at 403. The creation of the canal reversed the flow of the Chicago River, resulting in it flowing from Lake Michigan to the Mississippi River. *Id.* This diversion of water from Lake Michigan spawned multiple legal battles between Great Lakes states at the U.S. Supreme Court. *See id.*; *Wisconsin v. Illinois*, 281 U.S. 696 (1930) *modified,* 352 U.S. 984 (1957) and *supplemented,* 289 U.S. 395 (1933); *Wisconsin v. Illinois*, 388 U.S. 426 (1967), *modified,* 449 U.S. 48 (1980); *see also Missouri v. Illinois*, 200 U.S. 496 (1906).

6. Constitutional Authority

Under the Commerce Clause of the U.S. Constitution, the federal government exercises plenary power over navigable waters.

> The Commerce Clause confers a unique position upon the Government in connection with navigable waters. "The power to regulate commerce comprehends the control for that purpose, and to the extent necessary, of all the

> navigable waters of the United States. . . . For this purpose they are the public property of the nation, and subject to all the requisite legislation by Congress."

United States v. Rands, 389 U.S. 121, 122 (1967) (quoting *Gilman v. City of Philadelphia*, 70 U.S. 713, 725 (1865)). Moreover, the government's power is not limited to dealing with navigation:

> In truth the authority of the United States is the regulation of commerce on its waters. Navigability, in the sense just stated, is but a part of this whole. Flood protection, watershed development, recovery of the cost of improvements through utilization of power are likewise parts of commerce control. . . . The Congressional authority under the commerce clause is complete unless limited by the Fifth Amendment.

United States v. Appalachian Elec. Power Co., 311 U.S. 377, 426-27 (1940); *see also PPL Montana, LLC v. Montana*, 132 S. Ct. 1215, 1229 (2012); *Kaiser Aetna v. United States*, 444 U.S. 164, 173-174 (1979).

The Chicago River, Chicago Sanitary Ship Canal, and Illinois Waterway fall within the navigation servitude. The Corps has determined that they are navigable waters of the United States. *See* Navigable Waters of the United States, CHI. DIST., U.S. ARMY CORPS OF ENG'RS, http://www.lrc.usace.army.mil/Missions/Regulatory/NavigableWaters.aspx (last visited 14 Feb. 2013); Navigable Waters (Section 10) of the United States (Traditional), ROCK ISLAND DIST., U.S. ARMY CORPS OF ENG'RS, http://www.mvr.usace.army.mil/Portals/48/docs/regulatory /navwaters.pdf (last visited 14 Feb. 2013). The Supreme Court has also repeatedly exercised jurisdiction over the management of these waterways. *See, e.g.*, *Wisconsin v. Illinois*, 278 U.S. 367, 417 (1929) (holding that Section 10 permit was appropriate federal exercise of authority over canal).

7. Specific Statutory Authority

The Illinois Waterway

The Corps was given authority for operation and maintenance of the Illinois Waterway in the Rivers and Harbors Acts of 1927, 1930, and 1935. *See* Rivers and Harbors Act of 1927, ch. 47, 44 Stat. 1010, 1013-14; Rivers and Harbors Act of 1930, ch. 847, 46 Stat. 918, 929; Rivers and Harbors Act of 1935, ch. 831, 49 Stat. 1028, 1035.

The House report accompanying the 1930 Rivers and Harbors Act provides a detailed description of the history of the Illinois Waterway project. *See* H.R. REP. NO. 71-1265, at 136–140 (1930). The State of Illinois commenced construction of the project in 1921, and contemplated four locks and dams and a fifth lock forming the connection with the Chicago Sanitary Canal at Lockport. Illinois's constitution prohibited the construction of waterways, but a 1908 constitutional amendment authorized the $20 million bond thought sufficient to construct the waterway, with the bond repaid with proceeds from power generation on the waterway. By 1930, the state recognized that hydropower would never generate enough revenue to finance construction of the waterway and that the $20 million bond was insufficient to complete construction. Faced with the daunting process of seeking another constitutional amendment, the state asked the federal government to take over construction of the waterway.

The Secretary of War, concerned about recommending the expenditure of federal funds to complete a state waterway, solicited the opinion of the U.S. Attorney General regarding federal authority over the completed waterway. The U.S. Attorney General's opinion (included in Senate Document 71-126) concludes that irrespective of Illinois Governor Emmerson's disavowal of state authority over the waterway,[1] relying solely on the Constitution, the federal government had plenary control over the waterway and could "provide for and insure to the public perpetual, free navigation." S. DOC. NO. 71-126, at 68 (1930).

The federal channel of the Chicago River was set to 21 feet depth by the Rivers and Harbors Act of 1899, ch. 425, 30 Stat. 1121, 1156. Federal navigation improvements for the mainstem and North Branch portions of the Chicago River were authorized by the Rivers and Harbors Acts of 1899, 1902, 1907, 1919, and 1946. *See* Rivers and Harbors Act of 1899, ch. 425, 30 Stat. 1121, 1156; Rivers and Harbors Act of 1902, ch. 1079, 32 Stat. 331, 363; Rivers and Harbors Act of 1907, ch. 2509, 34 Stat. 1073, 1102; Rivers and Harbors Act of 1919, ch. 95, 40 Stat. 1275, 1283 (approving improvements provided by H.R. DOC. 64-1294); Rivers and Harbors Act of 1946, ch. 595, 60 Stat. 634, 636 (approving improvements provided by H.R. DOC. 78-767).

Chicago Harbor Lock

The Chicago Harbor Lock was constructed by the Chicago Sanitary District (now the Metropolitan Water Reclamation District) by specific order of the U.S. Supreme Court. *Wisconsin v. Illinois*, 289 U.S. 395, 412 (1933). The Supreme Court was forced to order its construction because Illinois had "inexcusably" failed to comply with the Court's 1930 decree to limit diversion from Lake Michigan. *Id.* at 407. In that 1930 decree, the Court had concluded that by opening the canal and allowing a flow of water from Lake Michigan of about 8500 cubic feet per second, the Chicago Sanitary District and State of Illinois were responsible for lowering the level of Lake Michigan by six inches. *Wisconsin v. Illinois*, 278 U.S. at 407. The lock was constructed to permit the state to limit the flow of water out of the Lake to 3200 cfs. Construction was completed in 1938.

In Section 107 of the Energy and Water Development Appropriation Act of 1982, Pub. L. No. 97-88, 95 Stat. 1135, 1137 (1981), Congress directed the Corps to use any appropriation for operation and maintenance of the Illinois Waterway to include the Chicago Sanitary and Ship

[1] "On behalf of the State of Illinois I disavow here and hereafter any claim or claims to the contrary, on condition, however, that the Federal Government do adopt and complete said waterway section and appropriate moneys to defray the cost thereof, as may be required in excess of the remaining balances in the Illinois Waterway fund, as hereinbefore indicated, the State reserving therefrom the amounts required for bridge construction work specified, and for necessary and required expenditures by the State from such funds for the protection, maintenance, or prosecution of said work, until such time as the Federal Government may assume control thereof by approprite act of Congress, or by other constituted authority." S. DOC. NO. 71-126, at 70-71(1930) (quoting letter from Illinois Governor Emmerson to the White House).

Canal. Congress then further clarified in the supplemental appropriations act passed in July 1983 that this authority is meant to include the Chicago Harbor Lock: "Section 107 of Public Law 97-88 pertaining to maintenance and operation of the Chicago Sanitary and Ship Canal of the Illinois Waterway in the interest of navigation includes the Control Structure and Lock in the Chicago River, and other facilities as are necessary to sustain through navigation from Chicago Harbor on Lake Michigan to Lockport on the Des Plaines River." Pub. L. No. 98-63, 97 Stat. 301, 311 (1983). House Report 97-850[2] explains this language:

> In providing appropriations for FY 1982, the Committee inserted language enacted in PL 97-88 to clarify the responsibilities of the Corps of Engineers for operations and maintenance of the Illinois Waterway, particularly with respect to the Chicago Sanitary and Ship Canal which heretofore has been operated and maintained by the Metropolitan Sanitary District of Chicago (MSD). The intent was to make it clear to the Corps of Engineers that their historic responsibilities for navigation on the Illinois waterway encompassed the entire waterway from Grafton, Illinois on the Mississippi River to Chicago Harbor on Lake Michigan and that local interests (MSD) would be responsible for sharing in costs of features that also served sanitation or other local purposes as determined to be appropriate. The Corps of Engineers now finds that according to its reports, the Chicago Sanitary and Ship Canal starts at Damen Avenue in Chicago and therefore does not include the controlling works and Lock in the Chicago River which provides the connection for navigation into Chicago Harbor on Lake Michigan. The purpose of the language in bill is to provide further clarification of the intent of Congress.

H.R. REP. NO. 97-850, at 145 (1983).

Maintenance of the Chicago Harbor is authorized under the Rivers and Harbors Acts of 1870, 1880, 1899, 1911, 1919, 1930, and 1962. *See* Rivers and Harbors Act of 1870, ch. 240, 16 Stat. 223, 226; the Rivers and Harbors Act of 1880, ch. 211, 21 Stat. 180, 182; the Rivers and Harbors Act of 1899, ch. 425, 30 Stat. 1121, 1129; the Rivers and Harbors Act of 1911, ch. 166, 36 Stat. 933, 947-48; the Rivers and Harbors Act of 1919, ch. 95, 40 Stat. 1275, 1283; the Rivers and Harbors Act of 1930, ch. 847, 46 Stat. 918, 942; and the Rivers and Harbors Act of 1962, Pub. L. No. 87-874; 76 Stat. 1173, 1176.

The Corps of Engineers was forbidden by the 2003 Energy and Water Development Appropriations Act from ever spending any funds related to a Chicago Harbor Visitor Center. *See* Energy and Water Development Appropriations Act, 2003 § 102, Consolidated Appropriations Resolution, 2003, Pub. L. No. 108-7, 117 Stat. 11, 139.

[2] In the Conference Report accompanying the Further Continuing Appropriation Act, Pub. L. No. 97-377, 96 Stat. 1830 (1982), agencies "under the jurisdiction of the Energy and Water Development Subcommittee" (such as the Corps), were directed to use House Report 97-850 and Senate Report 97-673 to implement the resolution. *See* H.R. REP. NO. 97-980, at 184-85 (1982) (Conf. Rep.).

Thomas J. O'Brien Lock and Controlling Works

The T.J. O'Brien[3] Lock and Controlling Works is a component of the Illinois Waterway and Upper Mississippi River inland waterway navigation system (UMRS). Construction, operation, and maintenance of the lock system with associated dams and 9-foot channel depth for the Illinois Waterway was authorized by the Rivers and Harbors Act of 1930. Authorizing legislation for navigation improvements to the Calumet-Sag Channel, including the removal of the Blue Island Lock and construction of T.J. O'Brien, was provided in the Rivers and Harbors Act of 1945, ch. 19, 59 Stat. 10, 19 (authorizing the project described in House Document No. 76-145, which recommended construction in the Little Calumet River "a lock of suitable dimensions for barge navigation to prevent reversals of flow and to regulate water levels and water diversion") and the Rivers and Harbors Act of 1946, ch. 595, 60 Stat. 634, 636 (authorizing the improvements to the Grand Calumet River and Illinois Waterway described in House Document 79-677, including "removal of Blue Island lock and construction of a lock and control works in Calumet River near its head and of similar structures in the proposed Grand Calumet Channel west of the Indiana Harbor Canal"). Construction of T.J. O'Brien was completed in 1960.

Lockport Lock

The Lockport Lock was designed by the State of Illinois and partially constructed over a period from 1923 to 1930. When the federal government took over construction of the Illinois Waterway, construction of the lock was completed in 1933.

8. Specific Regulation

Construction of the Chicago Harbor Lock required the approval of a permit under Section 10 of the Rivers and Harbors Act of 1899. The Acting Chief of Engineers approved that permit "subject to the condition, among others, 'That the controlling works shall be maintained and operated by and at the expense of The Sanitary District of Chicago and its successors or assigns under the general supervision of the District Engineer in charge of the locality and subject to such rules and regulations as to operation as may be prescribed by the Secretary of War.'" Regulations to Govern the Operation of the Sanitary District Controlling Works and the Use, Administration, and Navigation of the Lock Constructed in Connection Therewith at the Mouth of the Chicago River, Chicago Harbor, 3 Fed. Reg. 2,139, 2,139 (Sept. 1, 1938).

Those regulations, in force since 1938, require the Chicago District Engineer to direct MWRD to maintain the water level at the west end of the Chicago Harbor Lock. *See* 33 C.F.R. § 207.420. The regulation requires the water level in the Chicago River to be lower than that of Lake Michigan, "except in times of excessive storm run-off into the river or when the level of the lake is below minus 2 feet, Chicago City Datum." With the exception of those two conditions,

[3] "Blind Tom" O'Brien was a Democratic congressman from Illinois from 1933-1964 (except from 1939-1942 when he served as Cook County Sheriff). As sheriff during Al Capone's reign, he earned his nickname because of his inability to find corrupt gambling operations despite the Illinois attorney general handing him a list of 1380 names and addresses of known gambling operators.

the water level at the west end of the lock must be between minus 0.5 foot CCD and minus 2.0 feet CCD. *Id.*

Similarly, the Cal-Sag channel has had regulations in place since 1939. *See* Calumet-Sag Channel, Ill., Chicago Sanitary District Controlling Works and the Use, Administration, and Navigation of the Lock Near Blue Island, 4 Fed. Reg. 1391 (Apr. 1, 1939). Those regulations, too, require that Sanitary District maintain the water level at the downstream end of the lock between -0.5 and -2.0 CCD, at the direction of the Chicago District Engineer, except when lake levels are below -2.0 or during periods of excessive storm run-off into the Illinois Waterway. 33 C.F.R. § 207.425. The regulation was revised in 1975 to reference the then-operational T.J. O'Brien Lock rather than the Blue Island Lock and to remove the duplicative regulations listed in 33 C.F.R. § 207.300. *See* Calumet-Sag Channel, Illinois, 40 Fed. Reg. 57358 (Dec. 9, 1975).

In 1997, the Corps repaired the Chicago Harbor Lock and placed bulkheads at the lock. Because of fears of flooding, the Chicago District sought and received permission from the Great Lakes and Ohio River Division to lower water levels within the CAWS. Noting that the applicable federal regulation specifically contemplated lower water levels in the case of excessive storm runoff, the Deputy Division Commander authorized the Chicago District to allow water levels at the Chicago Harbor Lock to fall below -2.0 CCD if excessive storm run-off was anticipated, so long as there are no adverse impacts to navigation and navigation interests are notified. Because the Great Lakes and Ohio River Division had authority only over the Chicago Harbor Lock, and not the O'Brien or Lockport locks, the opinion was coordinated with the Mississippi Valley Division. *See* Memorandum from Deputy Commander, Great Lakes & Ohio Riv. Div. to Commander, Chi. Dist., subject: Chicagoland Waterways Operation (23 Dec. 1997).

9. Agreements with MWRD

As noted above, operation and maintenance of the Chicago and Lockport locks was transferred from the Metropolitan Sanitary District to the Army Corps of Engineers in 1984. Under an agreement between the Corps and MSD signed in 1984, the Corps operates and maintains the Chicago Lock and adjoining guidewalls; maintains the canal banks, levees, and retaining walls; maintains the foundation, piers, and the dolphins at the Lockport Controlling Works; and operates and maintains the Lockport Lock. The MSD operates and maintains both control structures at the Chicago Lock, including the sluice gates; the MSD control room; the Lockport Controlling Works; and the Lockport powerhouse and generating machinery. *See* Memorandum of Understanding between the Department of the Army and the Metropolitan Sanitary District of Greater Chicago (13 Jan. 1984). Although the parties originally considered it, ownership of the Chicago Lock was not transferred to the Corps.

After execution of the MOU, the Chicago District asked the North Central Division to clarify the scope of the Corps's responsibilities considering that the Corps does not actually own the lock. The Division Commander replied: "[Y]ou should operate and maintain the lock in a manner consistent with operation and maintenance practices at Federally owned locks. Simply stated, we should 'act like we own it.'" Memorandum from Commander, N. Cent. Div. to Commander, Chi. Dist., subject: Chicago Lock Ownership (25 Apr. 1984).

In 1997, during planning for the Chicago Lock repair, questions arose about the operational and fiscal responsibility of MWRD considering the use of the Chicago Lock for purposes other than navigation. The lock repair was required to keep the lock operational for navigation purposes and thus was fully federally funded. But when there is a major precipitation event, the lock is typically opened at the direction of MWRD to allow excess storm water to backflow into Lake Michigan. At that time, the Chicago District opined that all other purposes of the Chicago Lock remain the operational and fiscal responsibility of MWRD:

> The Corps' basic responsibility at the lock is navigation. The arrangement made in 1984 did not transfer any authority regarding flood control or water depths [required by the CFR] from the MWRDGC to the Corps. It is the MWRDGC's responsibility to tell the Corps when the locks are to be opened to facilitate the draining of flood water from the Chicago River. When the water level starts to rise due to a flood event the sluice gates automatically open to allow excess water to escape into Lake Michigan. This happens without any input from the Corps. When the gates open MWRDGC notifies the lock master and tells him to shut down the locks until the flood event has passed. If the water flow gets too high for the sluice gates to handle then MWRDGC gets back to the lock master and directs him to open the locks to allow more water to flow into Lake Michigan.

Memorandum from Donald Valk, CELRC-RE to District Commander, CELRC-DE, subject: Operational and fiscal responsibility for the Chicago Locks (26 Nov. 1997). That memorandum concludes that if MWRD directed the Corps to remove the bulkheads to relieve flooding, MWRD would bear full responsibility: "Especially since the MWRDGC is the owner of the locks and is simply directing the Corps, as the operator of the locks, to operate the MWRDGC's property in a fashion that will cause financial detriment to the Corps." *Id.*

The O'Brien Lock is also governed by an agreement with MWRD. The 1966 agreement provides that the lock will be operated by the Corps. But the agreement also states that the Corps will, consistent with the requirements of navigation, operate the lock and the sluice gates "as directed by the Sanitary District" to assist in Lake Michigan diversion, maintain water levels below Lake Michigan, and provide emergency flood relief. *See* Agreement Between the United States of America and the Metropolitan Sanitary District of Greater Chicago for Operation of the Thomas J. O'Brien Lock & Dam in Connection with Lake Diversion, Flood Relief & Pollution (9 June 1966).

10. Diversion

After the opening of the Chicago Sanitary and Ship Canal in 1900, other Great Lakes states challenged the authority of Illinois to divert water from Lake Michigan. This protracted litigation resulted in a decree from the Supreme Court limiting the amount of water that the state can divert from the lake. The decree has been revisited several times. *See Wisconsin v. Illinois*, 281 U.S. 696 (1930) *modified,* 352 U.S. 984 (1957) and *supplemented,* 289 U.S. 395 (1933); *Wisconsin v. Illinois*, 388 U.S. 426 (1967), *modified,* 449 U.S. 48 (1980). In its current form, the decree authorizes Illinois to divert water at an annual rate of 3200 cfs, averaged over 40 years. The Corps of Engineers is responsible for accounting for the diversion. *See Wisconsin v. Illinois*, 449 U.S. 48, 49 (1980); Water Resources Development Act of 1986 § 1142, Pub. L. No. 99-662, 100

Stat. 4082, 4253. Annual reports of Lake Michigan diversion are published by the Chicago District and are available online. *See Lake Michigan Diversion Accounting Program*, CHI. DIST., U.S. ARMY CORPS OF ENG'RS, http://www.lrc.usace.army.mil/Missions/LakeMichiganDiversionAccounting.aspx (last visited Feb. 5, 2013).

The Supreme Court decree is not the only authority on diversion of Great Lakes water. The Boundary Waters Treaty of 1909 established the International Joint Commission to resolve water resources disputes between the United States and Canada and must approve any obstructions or diversions of Great Lakes water that affect natural flows or levels. Boundary Waters Treaty, U.S.-Gr. Brit.(for Can.), Jan. 11, 1909, 36 Stat. 2448. And in 1986, Congress prohibited the diversion or export of any water from the Great Lakes basin without the consent of all Great Lakes state governors. 42 U.S.C. § 1962d-20(d).

11. General Navigation Regulation

The Secretary of the Army has authority to prescribe rules for the use, administration, and navigation of the navigable waters of the United States. 33 U.S.C. § 1. Section 9 of the River and Harbors Act of 1899 prohibits the construction of any "bridge, causeway, dam, or dike" over or in a navigable waterway until the consent of Congress is obtained and the plans have been approved by either the Secretary of Transportation (for bridges and causeways) or the Chief of Engineers and Secretary of the Army (for dams and dikes). 33 U.S.C. § 401. Section 10 of that act prohibits the construction of any structure in a navigable waterway unless authorized by the Secretary of the Army as recommended by the Chief of Engineers. 33 U.S.C. § 403.

In addition to the specific regulations governing the Chicago and O'Brien locks, the Corps is governed by general navigation regulations. The regulations at 33 C.F.R. § 207.300 govern the O'Brien Lock. Under 33 C.F.R. § 209.180, the District Engineer may authorize the "temporary closure of a waterway for the construction of a structure or the performance of other work in the waterway," but only to the extent necessary and only after "careful consideration to the effect of any closure on through navigation."

Operations at the Chicago Lock and O'Brien and Lockport locks are also governed by water control manuals issued under the authority of Corps regulations. *See* U.S. ARMY CORPS OF ENG'RS, REG. 1110-2-240, ENGINEERING AND DESIGN, WATER CONTROL MANAGEMENT (8 Oct 1982); U.S. ARMY CORPS OF ENG'RS, REG. 1110-2-8156, PREPARATION OF WATER CONTROL MANUALS (31 Aug. 1995); U.S. ARMY CORPS OF ENG'RS, MAN. 1110-2-3600, MANAGEMENT WATER CONTROL SYSTEMS (30 Nov 1987).

12. General Environmental Statutes

Activities by the Corps are governed by a number of environmental statutes. One of the more significant environmental statutes is the Clean Water Act. This office has concluded that the Corps faces no liability under the Clean Water Act for its operation of the Chicago Lock. *See* Memorandum from Kevin Jerbi, CELRC-OC, to Kim Sabo, CELRC-OC, subject: Clean Water Act implications of low Lake Michigan water levels (3 Jan. 2013).

The other significant environmental statute is the National Environmental Policy Act, 42 U.S.C. §§ 4331–4370h. NEPA requires agencies to undertake an assessment of the environmental effects of their proposed actions prior to making decisions. In the recent past, the Corps has prepared environmental assessments when contemplating major repair work at the Chicago and O'Brien locks. The question of whether changes to lock operations or water control plans requires NEPA documentation will be further developed in another memorandum.

Though there are a great number of environmental statutes, only a few are directly related to the Corps's management of the CAWS. Executive Order 11,514 directs federal agencies to "protect and enhance the quality of the environment." 3 C.F.R. 902 (1966-1970).

13. Judicial Interpretation of "Through Navigation"

In the recent litigation regarding Asian carp, the district court agreed with the Corps that it did not have the authority to hydrologically separate the CAWS from Lake Michigan by permanently closing the Chicago Lock:

> [T]he Supplemental Appropriations Act does not require the Corps just to preserve navigation "in" the CAWS, but rather requires the Corps to preserve "through navigation" between Lake Michigan and the Des Plaines River. Plainly, this requires the defendants to maintain and operate the CAWS in a manner that allows ships and other vessels to transit between these two bodies of water.

Michigan v. U.S. Army Corps of Eng'rs, No. 10 C 4457, 2012 WL 6016926 (N.D. Ill. Dec. 3, 2012) (citing Supplemental Appropriations Act of July 30, 1983, Pub. L. No. 98-63, 97 Stat. 301, 309). Although that case is currently on appeal with the Seventh Circuit, it remains today the only judicial opinion construing the meaning of the statutory command to sustain through navigation.

14. Analysis

The Corps's primary responsibility with respect to the Chicago Lock and Illinois Waterway is to sustain through navigation. The statutory command to sustain through navigation is paramount, the constitutional authority regarding navigation is plenary, and the agreements with MWRD provide that the Corps will operate the locks for the purposes of navigation.

Even so, the responsibility to sustain navigation does not necessarily require that the Corps maintain lockage-on-demand under all circumstances. For example, Operations Order 2012-63 implemented "the [Inland Marine Transportation System] recommendations for the standard levels of service at the Corps of Engineers Lock and Dam sites in support of budgetary constraints while accomplishing the navigation mission." HEADQUARTERS, U.S. ARMY CORPS OF ENG'RS, USACE IMPLEMENTATION OF INLAND MARINE TRANSPORTATION SYSTEM (IMTS) PROCESS IMPROVEMENT, STANDARD LEVELS OF SERVICE (31 Jul. 2012). Annex A to that OPORD described several different levels of service that might be appropriate under certain circumstances, ranging from full service (24/7/365) at one extreme to commercial lockages by appointment only at the other. *Id.* at Annex A tbl. 1.

The authority to maintain the locks for navigation purposes also contemplates the need to occasionally close the locks for repairs or maintenance. Moreover, as noted above, there is specific regulatory authority to temporarily close a waterway "for the construction of a structure or the performance of other work in the waterway," but only to the extent necessary and only after "careful consideration to the effect of any closure on through navigation." 33 C.F.R. § 209.180.

What is less clear is the extent of the Corps's discretion to balance its obligation to protect the water quality of Lake Michigan with its navigation responsibilities by modifying lock operations. The Corps clearly must maintain navigation; modifying lock operations for a non-navigation purpose would be consistent with the agency's responsibility under various environmental laws and executive orders to preserve the environment where possible, at least to the extent that it is consistent with the navigation mission.

"It is undisputed the Corps has very broad discretion in the running of its navigational civil works. . . . The operation of the Corps' civil works projects . . . requires that the needs of navigation be balanced with other public interests, including recreational use of Corps property." *Buffington v. United States*, 820 F. Supp. 333, 334–35 (W.D. Mich. 1992) (citing 33 U.S.C. §§ 1, 540); *see also United States v. Hernandez*, 979 F. Supp. 70, 76 (D.P.R. 1997) *aff'd*, 187 F.3d 623 (1st Cir. 1998); *United States v. Alameda Gateway, Ltd.*, 953 F.Supp. 1106, 1110 (N.D. Cal. 1996).

The Chicago Harbor Lock is a structure authorized by a Section 10 permit granted in 1936. *See* 3 Fed. Reg. 2,139, 2,139. By virtue of that permit, the Corps retains the authority to revoke or modify the permit as necessary to serve the public interest. *See* 33 C.F.R. § 325.7. As the Corps's own regulations make clear:

> The U.S. Army Corps of Engineers has been involved in regulating certain activities in the nation's waters since 1890. Until 1968, the primary thrust of the Corps' regulatory program was the protection of navigation. As a result of several new laws and judicial decisions, the program has evolved to one involving the consideration of the full public interest by balancing the favorable impacts against the detrimental impacts. This is known as the "public interest review." The program is one which reflects the national concerns for both the protection and utilization of important resources.

33 C.F.R. § 320.1(a).

While generally mutually beneficial, the split priorities of MWRD and the Corps with respect to the locks could generate conflict. Typically when MWRD notifies the Corps of the need to open the lock gates for flood control purposes, navigation is essentially shut down due to the storm event, resulting in little impact on navigation. But if MWRD were to ask the Corps to operate the lock in a manner that would unreasonably impact navigation, the Corps would be within its authority to refuse the request.

15. Conclusion

The Corps is vested with great discretion in its operation of the Chicago Area Waterway System. Subject only to the command from Congress to sustain through navigation from Lockport to Lake Michigan, the Corps is empowered to consider the public interest in balancing the needs of navigation with other competing interests, including recreation and environmental protection. Although the Corps is primarily concerned with navigation with MWRD having primary responsibility for water quality, diversion, and flood control, MWRD's actions are always subject to the Corps's ultimate responsibility for the navigable waterway.

The federal government has plenary control over navigable waters; the only authority reserved specifically to Congress (rather than the Corps) is the authority to construct a dam or dike completely shutting off navigation.

16. Questions about this memorandum can be directed to me.

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Assistant District Counsel

References

1. *Wisconsin v. Illinois*, 278 U.S. 367 (1929).

2. *Wisconsin v. Illinois*, 281 U.S. 696 (1930) *modified,* 352 U.S. 984 (1957) and *supplemented,* 289 U.S. 395 (1933).

3. *Wisconsin v. Illinois*, 388 U.S. 426 (1967), *modified,* 449 U.S. 48 (1980).

4. *Missouri v. Illinois*, 200 U.S. 496 (1906).

5. Navigable Waters of the United States, CHI. DIST., U.S. ARMY CORPS OF ENG'RS, http://www.lrc.usace.army.mil/Missions/Regulatory/NavigableWaters.aspx.

6. Navigable Waters (Section 10) of the United States (Traditional), ROCK ISLAND DIST., U.S. ARMY CORPS OF ENG'RS, http://www.mvr.usace.army.mil/Portals/48/docs/regulatory/navwaters.pdf.

7. Rivers and Harbors Act of 1927, ch. 47, 44 Stat. 1010, 1013-14

8. Rivers and Harbors Act of 1930, ch. 847, 46 Stat. 918, 929, 942

9. Rivers and Harbors Act of 1935, ch. 831, 49 Stat. 1028, 1035.

10. H.R. REP. NO. 71-1265 (1930).

11. S. DOC. NO. 71-126 (1930).

12. Rivers and Harbors Act of 1899, ch. 425, 30 Stat. 1121, 1129, 1156

13. Rivers and Harbors Act of 1902, ch. 1079, 32 Stat. 331, 363

14. Rivers and Harbors Act of 1907, ch. 2509, 34 Stat. 1073, 1102

15. Rivers and Harbors Act of 1919, ch. 95, 40 Stat. 1275, 1283.

16. H.R. DOC. 64-1294.

17. Rivers and Harbors Act of 1946, ch. 595, 60 Stat. 634, 636.

18. H.R. DOC. 78-767.

19. *Wisconsin v. Illinois*, 289 U.S. 395 (1933).

20. Energy and Water Development Appropriation Act of 1982 § 107, Pub. L. No. 97-88, 95 Stat. 1135, 1137 (1981).

21. Supplemental Appropriations Act of 1983, Pub. L. No. 98-63, 97 Stat. 301, 311 (1983).

22. H.R. REP. NO. 97-850, at 145 (1983).

23. Rivers and Harbors Act of 1870, ch. 240, 16 Stat. 223, 226

24. Rivers and Harbors Act of 1880, ch. 211, 21 Stat. 180, 182

25. Rivers and Harbors Act of 1911, ch. 166, 36 Stat. 933, 947-48.

26. Rivers and Harbors Act of 1962, Pub. L. No. 87-874; 76 Stat. 1173, 1176.

27. Rivers and Harbors Act of 1945, ch. 19, 59 Stat. 10, 19 (authorizing the project described in House Document No. 76-145)

28. H.R. DOC. 76-145.

29. H.R. DOC. 79-677.

30. Regulations to Govern the Operation of the Sanitary District Controlling Works and the Use, Administration, and Navigation of the Lock Constructed in Connection Therewith at the Mouth of the Chicago River, Chicago Harbor, 3 Fed. Reg. 2,139 (Sept. 1, 1938).

31. 33 C.F.R. § 207.420.

32. Calumet-Sag Channel, Ill., Chicago Sanitary District Controlling Works and the Use, Administration, and Navigation of the Lock Near Blue Island, 4 Fed. Reg. 1391 (Apr. 1, 1939).

33. 33 C.F.R. § 207.425.

34. Calumet-Sag Channel, Illinois, 40 Fed. Reg. 57358 (Dec. 9, 1975).

35. Memorandum from Deputy Commander, Great Lakes & Ohio Riv. Div. to Commander, Chi. Dist., subject: Chicagoland Waterways Operation (23 Dec. 1997).

36. Memorandum of Understanding between the Department of the Army and the Metropolitan Sanitary District of Greater Chicago (13 Jan. 1984).

37. Memorandum from Commander, N. Cent. Div. to Commander, Chi. Dist., subject: Chicago Lock Ownership (25 Apr. 1984).

38. Memorandum from Donald Valk, CELRC-RE to District Commander, CELRC-DE, subject: Operational and fiscal responsibility for the Chicago Locks (26 Nov. 1997).

39. Agreement Between the United States of America and the Metropolitan Sanitary District of Greater Chicago for Operation of the Thomas J. O'Brien Lock & Dam in Connection with Lake Diversion, Flood Relief & Pollution (9 June 1966).

40. Water Resources Development Act of 1986 § 1142, Pub. L. No. 99-662, 100 Stat. 4082, 4253.

41. Boundary Waters Treaty, U.S.-Gr. Brit.(for Can.), Jan. 11, 1909, 36 Stat. 2448.

42. 42 U.S.C. § 1962d-20(d).

43. 33 U.S.C. § 1.

44. 33 U.S.C. § 403.

45. 33 C.F.R. § 207.300.

46. 33 C.F.R. § 209.180

47. Executive Order 11,514, 3 C.F.R. 902 (1966-1970).

48. *Michigan v. U.S. Army Corps of Eng'rs*, No. 10 C 4457, 2012 WL 6016926 (N.D. Ill. Dec. 3, 2012).

49. 33 C.F.R. § 325.7.

50. 33 C.F.R. § 320.1.

SUMMARY OF THE CHICAGO AREA WATERWAYS SYSTEM OPERATION

EXHIBIT C

C-1. General. Exhibit C provides a summary of the current Metropolitan Water Reclamation District (MWRD) Waterways Operation Plan. For specifics regarding operation of the Waterways including revisions one should contact MWRD. The responsibility for the control of the discharge of water from the Chicago Sanitary and Ship Canal (CSSC) at Lockport Powerhouse and Lockport Controlling Works resides with the System Dispatcher of the MWRD. Furthermore, the Systems Dispatcher controls the water levels in the upstream tributary canal system which ultimately connects to Lake Michigan at the Wilmette Pumping Station, Chicago Harbor Lock and Chicago River Controlling Works, and the Thomas J. O'Brien Lock and Controlling Works.

C-2. Waterways Operation during Dry Weather. During periods of dry weather MWRD controls the discharge of water from the Chicago and Sanitary and Ship Canal at the Lockport Powerhouse such that the Waterways do not reverse into Lake Michigan while maintaining normal navigation and water quality.

C-2.1. Dry Weather Limits on Waterway Elevations. For elevations of Lake Michigan greater than -1.80 feet CCD, the waterway elevations in Table C-1 are in force. For lake levels below -1.80 feet CCD see section C-2.2.2. Note that the system is generally flat and maintaining the elevations at the Chicago River Controlling Works and the O'Brien Lock will govern.

Table C-1 Dry Weather Limits on Waterways Elevations

Elevation Gage	Lower Limit (1)	Upper Limit	Ideal Level (4)
Chicago River Controlling Works	-2.00 CCD	-0.50 CCD (2)	-2.00 CCD
O'Brien Lock and Dam	-2.00 CCD	-0.50 CCD (2)	-2.00 CCD
Sag Junction	-4.00 CCD	-1.80 CCD (3)	
Lockport Controlling Works	-10.00 CCD	-2.00 CCD (3)	

1. The Lower Limits are set to maintain minimal navigational depths of the channel.
2. The Upper Limits at CRCW and Thomas J. O'Brien Lock and Dam are set to prevent unintentional reversal into Lake Michigan.
3. The Upper Limits of the Sag Junction as well as the LCW are set to prevent washout of the soil banks of the Canal at the LPH.
4. The Ideal Level provides the greatest level of flood protection, by maintaining the highest allowable capacity available for the transportation of storm runoff.

C-2.2. Unusual Waterways Elevations.

C-2.2.1. Special Requests. Occasionally, special requests will be made by the U.S. Army Corps of Engineers or other interests with respect to specifying canal elevations. The requests must be authorized by the MWRD Canal Operations Engineer and required elevations are not to violate the minimum and maximum allowable elevations given in Table C-1.

C-2.2.2. Low Lake Michigan Elevation. When the elevation of Lake Michigan falls below -1.80 feet CCD, MWRD is permitted to operate the waterway at a lower water level. The canals are to be maintained at 0.20 to 0.50 feet below the level of the lake, but are not to fall below -3.00 feet CCD, without permission from the U.S. Army Corps of Engineers; see the letter of understanding between the U.S. Army Corps of Engineers and the Chief of Maintenance and Operations, dated May 20, 2003, shown in Exhibit H.

Except as noted in Section C-3.1.1, lockages at the Chicago Harbor Lock are to continue as they would during normal conditions.

C-2.3. Hierarchy of Waterways Discharge Control Methods. During dry weather conditions, the Canal discharge is to be controlled by the methods listed in the following order, unless otherwise directed by the Canal Operations Engineer.

1. Varying the flow through the two hydro-turbines at LPH.
2. Opening of one pit gate at LPH, if one hydro-turbine is unavailable.

To maintain hydraulic equilibrium, the elevations at both inlet points from Lake Michigan, CRCW and O'Brien Lock and Dam, will vary somewhat, in which case the elevation of the lowest should be as close to -2.00 feet CCD as possible. The Systems Dispatcher varies the flow at the LPH within the capacity of two generators to maintain levels in the Waterway System. In the event that only one generator is available, one pit gate may be used in its place.

C-2.4. Maintenance of Water Quality. MWRD is permitted to divert Lake Michigan waters to raise DO levels and improve the water quality in general. Additional details on discretionary diversions are contained in Section C-4, Discretionary Diversions.

C-3. Waterways Operation During Wet Weather. Supplemental operations are required when storm runoff is forecasted and/or occurring. These operations can be divided into three phases: preparation, on-going storm operations, and recovery. The following standard operating procedures are to be used as guidelines by the Systems Dispatcher for the Waterways operation with storm run-off.

C-3.1. Wet Weather Limits on Waterways Elevation. Unless the elevation of Lake Michigan is less than -1.80 feet CCD, the waterway elevations listed in Table C-2 are in force during periods immediately preceding and during storm run-off. Before taking action to lower the elevation at CRCW and Thomas J. O'Brien Lock and Dam below -

2.00 feet CCD, proper notification must be made in accordance with the call list on Form 4.1, Systems Dispatcher Manual. Form 4.1 specifies that the Lockport and Brandon Road Lockmasters are to be notified between 30 minutes and two hours before Lockport flows are to exceed 5,000 cfs and when flows exceed 7,000 cfs, at which point MWRD requests a broadcast to mariners. The Systems Dispatcher continues to call in flow changes throughout the event.

Table C-2 Wet Weather Limits on Waterways Elevations

Elevation Gage	Lower Limit (1,2)	Upper Limit	Ideal Level (4)
Chicago River Controlling Works	-3.00 CCD	-0.50 CCD (3)	-3.00 CCD
O'Brien Lock and Dam	-3.00 CCD	-0.50 CCD (3)	-3.00 CCD
Sag Junction	-4.00 CCD	-1.80 CCD	-4.00 CCD
Lockport Controlling Works	-10.00 CCD	-2.00 CCD	-10.00 CCD

1. MWRD is allowed to operate the inlet controlling works at a lowered elevation during periods of storm runoff. *
2. Lower Limits are set to maintain minimal navigational depths of the channel.
3. Upper Limits are set to prevent unintentional reversal into Lake Michigan.
4. The ideal level provides the greatest level of flood protection by maintaining the highest allowable capacity available for the transportation of storm run-off.

C-3.1.1. Lower Lake Michigan Elevation. If the elevation of Lake Michigan is less than -1.80 feet CCD, it becomes impossible to maintain the required elevation in the canal system during wet weather. Permission was granted from the U.S. Army Corps of Engineers to lower the canals below -3.00 feet CCD to a minimum of -4.00 feet CCD.

C-3.2. Hierarchy of Canal Discharge Control Methods. The canal discharge to be controlled, during wet weather conditions, by the methods listed in the following order, unless otherwise directed by the Canal Operations Engineer.

1. Maximizing the flow through the two hydro-turbines at LPH.
2. Opening up to nine pit gates at the LPH, three gates per pit.
3. Opening up to seven of the sluice gates at the LCW.

C-3.3. Waterways Preparation in Anticipation of a Storm. When a rain warning is received, MWRD closes lake water diversion intakes and brings the Waterway elevations at CRCW and O'Brien Lock and Controlling Works to the minimum possible levels without violating navigational requirements.

When a rain warning is received, notify the Managing Engineer. If they cannot be contacted within fifteen minutes, use Table C-3 Canal Drawdown Optimization as a guideline to determine the optimum elevation at CRCW and O'Brien Lock and Dam based on rainfall prediction and TARP capacities.

If Lake Michigan levels are above +3.0 CCD, then drawdown the canal to -3.0 CCD for any rain event with of a 60% chance of rainfall greater than 0.5 inches no matter the status of TARP.
If Lake Michigan levels are above +3.0 CCD, then seek approval with the Principal Engineer to drawdown the canal to -4.0 CCD for any rain event with the following conditions:

- Forecast of rain intensity greater than 1.0 inch per 12 hours or 2.0 inches per 24 hours
- Location of the rain event in the North and Central basins of Cook County
- Limited or no storage capacity of McCook tunnels and reservoirs
- High flows from the Stickney, O'Brien, and Calumet Water Reclamation Plants
- Saturated ground conditions or rain event with snowmelt
- High flows from the tributaries to the Chicago Area Waterway System

Table C-3 Canal Drawdown Optimization

Forecast Type	60% Chance Rainfall Prediction for a Duration of ≥ 8 hours	McCook TARP % Full	Canal Drawdown Elevation at CRCW and O'Brien L&D
Advisory	< 0.2"	< 50%	-2.00 CCD
Advisory	< 0.2"	≥ 50%	-2.00 CCD
Warning	≥0.2" to <0.4"	< 50%	-2.00 CCD
Warning	≥0.2" to <0.4"	≥ 50%	-2.00 CCD
Warning	≥0.4" to <0.6"	< 50 %	-2.00 CCD
Warning	≥0.4" to <0.6"	≥ 50 %	-2.50 CCD
Warning	≥0.6" to <0.8"	< 50 %	-2.50 CCD
Warning	≥0.6" to <0.8"	≥ 50 %	-2.50 CCD
Warning	≥0.8" to <1.0"	< 50 %	-2.50 CCD
Warning	≥0.8" to <1.0"	≥ 50 %	-3.00 CCD
Warning	≥ 1.0"	< 50 %	-3.00 CCD
Warning	≥ 1.0"	≥ 50 %	-3.00 CCD

C-3.4. Waterways Operation during a Storm. While the waterways are receiving storm water run-off, the elevation limits of the waterways are to be maintained within the limits listed in Section C-3.1, Wet Weather Limits on Waterways Elevation, or Section C-3.1.1, Low Lake Michigan Elevation, if so permitted. MWRD adjusts the discharge at LPH and LCW as necessary, in accordance with Section C-3.2 Hierarchy of Canal Discharge.

C-3.4.1. Holding Lockage at CRCW and Thomas J. O'Brien Locks. When the elevation of the Chicago River rises above the elevation of Lake Michigan as the result of a storm event, lockages must be held, except for in emergencies (fire boats, U.S. Coast Guard, and Police Marine units). The Lockmaster and the Chief of Operations from the Chicago District, USACE must be notified to implement the cessation of lockage at CRCW. Likewise, the Lockmaster and the Illinois Waterway Project Operations Manager must be notified regarding the cessation of lockage at Thomas J. O'Brien Lock.

C-3.4.2. Notification during Storm Operations.

1. If the discharge at the LPH exceeds 7,000 cfs, notification is to be made with the Canal Operations Engineer or a higher supervisor and those listed in Form 4.1, Lockport Powerhouse Drawdown Call Out Record.

2. To provide early notification that the canal will be drawn down MWRD notifies the following parties when it is anticipated that the flow at the Lockport Powerhouse will be increased above 5,000 cfs (i.e., capacity of one unit + more than one pit gate or capacity of two units + any pit gates). MWRD places the calls between 30 minutes and two hours before increasing the LPH flow over the 5,000 cfs threshold.

A. U.S. Coast Guard (414) 747-7182, 24hrs
B. Brandon Road Lock (815) 744-1714, 24hrs
C. Lockport Lock (815) 838-0536, 24hrs

3. In addition, any flow changes (increase or decrease) thereafter are transmitted to all three parties above.

C-3.5. Reversal to Lake Michigan. During periods of extreme storm run-off, it may become necessary to open sluice gates at WPS, CRCW, or Thomas J. O'Brien Lock to relieve high water elevations in the Waterway System. After the reversal MWRD reopens the gate where the reversal occurred in order to remove as much of the reversal water as possible from Lake Michigan.

C-3.5.1. Reversal at WPS. Reversal to the lake at the WPS should commence when the North Shore Channel elevation reaches +4.50 CCD, and the following is true:

1. Rain continues to fall in the WPS Area and there is indication that the elevation will continue to rise with the probability of exceeding +5.00 CCD, which is the elevation of the top of the sluice gate while closed; or

2. The Northside WRP is pumping at maximum capacity and the North Branch Pump Station (NBPS) is discharging to the river.

3. The on-site Electrical Operator (EO) confirms the water elevation readings.

If significant precipitation is not occurring and water levels are rising slowly, the discharge to the lake should be held until the level reaches +5.00 CCD. After the Principal Engineer or their designee gives permission to open the gate, the EO is open the gate 4 feet and wait for further direction from the Systems Dispatcher to move the gate either up or down. When the water starts to recede, the gate should be closed in steps to maintain the elevation between +4.00 CCD and +4.50 CCD for as long as possible to minimize the volume of reversal.

C-3.5.2. Reversal at WPS During High Lake Michigan Levels. If the Lake Michigan levels are above +4.50 CCD, then hold the reversed until the elevation of the North Shore Channel is higher than the level of the Lake. If we are approaching a condition which we cannot reverse at +4.5 CCD because of high Lake Michigan levels, the notify the Chicago Office of Emergency Management (DEMC) at 312-746-9111.

C-3.5.3. Reversal at CRCW. Reversal to the lake at the CRCW should commence when the river level reaches +3.00 CCD and there is an indication that the elevation will continue to rise with the possibility of exceeding +3.50 CCD. If significant precipitation is not occurring and water levels are rising slowly, the discharge to the lake should be held until the level reaches +3.50 CCD. Reversal through the intake sluice gates should be maximized before using the USACE sector gates at the Chicago Harbor Lock. The South sluice gates at CRCW are to be used first, followed by the North sluice gates, and finally, the sector gates.

C-3.5.4. Reversal at CRCW During High Lake Michigan Levels. If the Lake Michigan Levels are above +3.00 CCD, then hold the reversal until the elevation at CRCW is higher than the level of the Lake. If we are approaching a condition which we cannot reverse at +3.00 CCD because of high Lake Michigan water levels, then notify the Chicago Office of Emergency Management (OEMC) at 312-746-9111. Reversal through USACE Chicago Harbor Lock sector gates first, then open CRCW South sluice gates followed by CRCW North sluice gates.

C-3.5.5. Reversal at the Thomas J. O'Brien Lock and Dam. Reversal to the Lake at the O'Brien Lock and Dam should commence when the river level reaches +3.00 CCD and there is an indication that the elevation will continue to rise with the possibility of exceeding +3.50 CCD. If precipitation is not occurring and water levels are rising slowly, the discharge to the Lake should be held until the level reaches +3.50 CCD. Reversal through the intake sluice gates should be maximized before using the USACE O'Brien Lock sector gates.

C-3.5.6. Reversal at the O'Brien Lock and Dam, during High Lake Michigan Levels. If the upper O'Brien levels are above +3.00 CCD, then hold the reversal until the elevation of the lower O'Brien is higher than the level of the upper O'Brien. If Lake Michigan water levels are too high to allow to reverse at +3.00 CCD, then notify the Chicago Office of Emergency Management (OEMC) at 312-746-9111. Reversal through the USACE O'Brien Lock sector gates first, then open sluice gates.

C-3.6. Waterways Recovery from Storm Operations. Following the cessation of precipitation, and the subsequent reduction of storm run-off into the Waterways, the discharge out of the Canal System needs to be similarly reduced to avoid overdrawing the Canal and thus not maintain the required navigation depth. The canal is to be brought back to dry weather elevations within six hours of the “All Clear” for a storm warning if there is no significant pending precipitation shown on the weather radar and the meteorologist has not indicated the possibility of significant upcoming rainfall. (An advisory of less than 0.2” of rain does not constitute the possibility of significant rainfall.)

As runoff and water levels recede the operations to control the discharge follow the plan in the reverse order as given in Section C-3.2 Hierarchy of Canal Discharge Methods. If the elevations at CRCW and Thomas J. O’Brien intakes remain below minimum navigation levels after 6 hours, the intake gates shall be opened as necessary to achieve the elevation ranges listed above as quickly as possible. This diversion water is accounted for as navigational makeup diversion. See Section C-5 for further details on navigational makeup diversion.

C-4. Discretionary Diversions. Effective in water year 2018, the MWRD’s discretionary diversion is 220 CFS. Intake points from Lake Michigan are located at the WPS, the CRCW, and the O’Brien Lock and Dam.

Elevated water temperatures in the summer months and lower dissolved oxygen levels in the Chicago Area Waterways normally dictate a higher need for diversion.

Upon receipt of any forecast of rain and/or acknowledgement of impending rain via radar information, the discretionary diversion at Wilmette is stopped. If a rain warning is received, discretionary diversion shall be stopped at all three intake locations.

C-5. Navigation Makeup Diversion. Following the cessation of storm operations, it may be necessary to divert Lake Michigan water into the waterway system to compensate for canal drawdown in order to maintain navigational depths. The District has been allocated 35 cfs for navigational makeup diversion by the Illinois Department of Natural Resources. These diversions are particularly necessary following canal drawdown in preparation for storms that do not materialize or produce insignificant run-off.

STANDING INSTRUCTIONS TO LOCKMASTER

EXHIBIT D

D-01. Instructions to the Lockmaster. The Chicago District operates the Locks at two of the three navigation projects within the Chicago Area Waterways. The operation of the Lockport Lock is the responsibility of the respective Lockmaster. In his absence, it becomes the responsibility of the Assistant Lockmaster or the shift head on duty at the time. The regulation of structures within the Chicago Area Waterways System (CAWS) for water control purposes is under the jurisdiction of the Metropolitan Water Reclamation District. The Lockmasters are responsible for recording hydrometeorological data into the LPMS system as described in Section 5-06.

D-02. Pool Regulation. As stated above, MWRD is responsible for the regulation of the water control structures within CAWS. Information regarding the operation of the Chicago Area Waterway System under the jurisdiction of the Metropolitan Water Reclamation District is found in Chapter 7 and Exhibit C.

a. Normal Operation. MWRD operates the waterways to maintain navigation within prescribed limits typically around -2.0 CCD during normal operation. Details regarding the operation of CAWS during normal conditions are given in Exhibit C; section C-2, “Waterways Operation during Dry Weather.” Under dry weather conditions water may diverted from Lake Michigan by opening the sluice gates at the T.J. O’Brien Controlling Works. The Lockmaster and/or his designated staff operate the sluice gates as directed by MWRD. Water levels are controlled within CAWS by adjusting the flow through the turbines at the Lockport Powerhouse. When flow changes are made at the Lock Powerhouse, the System Dispatcher notifies the Lockmaster at Lockport Lock. The Lockmaster at Brandon Lock and Dam is also notified so that they can adjust gates accordingly to maintain the navigation pool. The notification must be made as soon as possible because the travel time between the Lockport Powerhouse and Brandon Road Lock and Dam is only 20 minutes.

b. Flood Operation. A summary of the procedures used by MWRD during storm conditions are given in section C-3; “Waterways Operation during Wet Weather.” When a forecast of rain is received the diversion of water at Wilmette Pumping Station is stopped. Diversion at the Chicago and T.J. O’Brien controlling Works are also stopped as rainfall begins. As described in section 7-05, when storms are forecasted, MWRD increases the discharge at the Lockport Powerhouse prior to the start of the storm. In addition to increasing discharge to account for the increase of flow coming down the Chicago Sanitary and Ship Canal, the System Dispatcher may start to drawdown the pool to increase channel conveyance and storage capacity. The Lockport pool can be drawn down as much 8 feet to -10.0 feet CCD providing water level at the Cal-Sag junction does not go below -4.0 feet CCD and the lower limits at the Wilmette Pumping Station, the Chicago Lock and Controlling Works, and the T.J. O'Brien Lock and Controlling works as given in table C-2 are not compromised. The Lockport controlling Works gates are opened as needed as conditions warrant. The canal is operated to maximize the amount of water being evacuated from the waterways through Lockport without compromising navigation. Because it generally takes four hours for a gate operation to establish an efficient upstream flow pattern, the gate operation must be made well in advance of the storm to minimize upstream water level increases. During Wet Weather Operations MWRD is to contact the Lockmasters at Lockport Lock and Brandon Road Lock and Dam regarding changes in flow at the Lockport Powerhouse and Controlling Works.

Reversals of flow into Lake are allowed as a last resort when the water levels continue to rise, and flooding becomes a primary focus, and the following conditions are met. The Chicago River Controlling Works and the T.J. O'Brien Controlling Works are opened to allow stormwater to flow into Lake Michigan when the river levels reach +3.0 feet CCD (582.5 feet NGVD) and there is any indication that the river will continue to rise with the possibility of exceeding +3.5 feet CCD (583.0 feet NGVD). Sector gates are opened up as a last resort at the Chicago Lock and T.J. O'Brien Lock. If significant precipitation is not occurring and water levels are rising slowly, the discharge to the lake should be held until the level reaches +3.5 feet CCD (583.0 feet NGVD). Discharge to the lake through the Wilmette Pumping Station occurs when the elevation of the North Shore Channel reaches +4.5 CCD (584.0 feet NGVD) and there is any indication that the river will continue to rise with the possibility of exceeding +5.0 feet CCD (584.5 feet NGVD). The Lockmasters may be directed to close down the locks at some point during a storm as directed by MWRD.

D-03. Emergency Regulation. As stated in section 7-05, g, an "emergency" is considered to exist when computer, telephone (cell phone), or radio communications cannot be established between the Lockmaster and the home office, or between the U.S. Army Corps of Engineers and MWRD. Other emergency conditions can exist which may pose a significant hazard to life and/or property. These conditions may include embankment failure, extreme storms, excess seepage, sabotage, dam failure, and lock gate failure. During these situations, the operation of the Lockport Lock and Dam, the Lockport Controlling Works, and the Chicago Sanitary and Ship Canal retaining walls will be administered in accordance with provisions contained in the U.S. Army Corps of Engineers publication, "Emergency Action Plan for Lockport Lock and Controlling Works,' The Emergency Action Plan contain up to date notification lists.

MEMORANDUM OF AGREEMENT BETWEEN THE UNITED STATES OF AMERICA AND THE METROPOLITAN SANITARY DISTRICT OF GREATER CHICAGO FOR OPERATION OF THE THOMAS J. O'BRIEN LOCK & DAM IN CONNECT WITH LAKE DIVERSION, FLOOD RELIEF & POLLUTION

EXHIBIT E

COPY r' 'ped 8-4-76

AGREEMENT BETWEEN
THE UNITED STATES OF AMERICA
AND
THE METROPOLITAN SANITARY DISTRICT OF GREATER CHICAGO
FOR OPERATION OF
THE THOMAS J. O'BRIEN LOCK & DAM
IN CONNECTION WITH
LAKE DIVERSION, FLOOD RELIEF & POLLUTION

This Memorandum of Agreement, entered into this 9th day of June 1966, by and between the United States of America (hereinafter referred to as the "Government"), represented by the District Engineer executing this Agreement, and the Metropolitan Sanitary District of Greater chicago (hereinafter referred to as the "Sanitary District"), a corporation of the State of Illinois. WITNESSETH:

1. The Government-owned Thomas J. O'Brien Lock & Dam, on the Calumet River (Illinois Waterway) near 134th Street, Chicago, Illinois, 326.4 miles above the Mississippi River at Grafton, Illinois, will be operated by the Chicago District Corps of Engineers for the Government. In addition to operating the lock for navigation, the Government will, consistent with the requirements of navigation, also operate the lock and the sluice gates as directed by the Sanitary District in order to:

a. Assist in the control of diversion from Lake Michigan.

b. Maintain the water surface at the south (downstream) end of the lock at or below the level of Lake Michigan except in times of excessive storm runoff into the watersheds downstream of the lock. Except as so noted the water surface at the south (downstream) end of the lock normally shall be held to minus 2.0 feet, Chicago City Datum.

c. Provide emergency flood relief by permitting temporary lakeward flows through the lock and dam in order to reduce flood damage from storm water runoff into the Little and Grand Calumet Rivers.

2. The following procedure is established in order to accomplish the above:

a. The Sanitary District will:

(1) Advise the Chicago District, Corps of Engineers by letter the names of all personnel authorized to order changes in the position of the lock and sluice gates. The lock gates will be held only in the fully closed or opened position.

(2) Such requests by any authorized employees will be made direct by telephone or any other means to the Chicago District, Corps of Engineers employee in charge of the lock at the time.

(3) In every instance, maintain a record of the name of the Sanitary District employee issuing the directive; the name of the Chicago District, Corps of Engineers employee contacted; the explicit instructions given, together with the date and time issued as well as time and date the directed operation was completed.

b. The Government, through the Chicago District, Corps of Enginers Lockmaster or his representative in charge of the O'Brien Lock & Dam will:

(1) Prompty activate the lock and sluice gates as directed insofar as such action will not unreasonably interfere with navigation.

(2) Advise the Sanitary District of the date and time directed operation was completed.

(3) Maintain a record of the name of the Chicago District lock employee receiving the directive; the name of the Sanitary District employee directing the change; the explicit instructions with date and time received; the date and time the directed action was completed; the time and completed action was reported to the Sanitary District, and the person to whom this was reported.

3. The Sanitary District shall hold and save the Government free from damages due to actions taken under this agreement.

In Witness Whereof, the parties hereto have executed this Memorandum of Agreement as of the day and year first above written.

THE METROPOLITAN SANITARY DISTRICT OF GREATER CHICAGO

BY: [redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

<u>MEMORANDUM OF AGREEMENT BETWEEN THE DEPARTMENT OF THE ARMY AND THE METROPOLITAN SANITARY DISTRICT OF GREATER CHICAGO</u>

<u>EXHIBIT F</u>

Current as of 2010

MEMORANDUM OF AGREEMENT BETWEEN THE DEPARTMENT OF THE ARMY AND THE METROPOLITAN SANITARY DISTRICT OF GREATER CHICAGO

WHEREAS Section 107 of Public Law 97-88 provided as follows: "Funds herein or hereinafter made available to the Corps of Engineers-Civil for operation and maintenance of the Illinois Waterway shall be available to operate and maintain the Chicago Sanitary and Ship Canal portion of the Waterway in the interest of navigations."; and

WHEREAS Public Law 98-63 provided as follows: "Section 107 of Public Law 97-88 pertaining to maintenance and operation of the Chicago Sanitary and Ship Canal of the Illinois Waterway in the interest of navigation includes the Control Structure and Lock in the Chicago River and other facilities as are necessary to sustain through navigation from Chicago Harbor on Lake Michigan to Lockport on the Des Plaines River."; and

WHEREAS the Metropolitan Sanitary District of Greater Chicago (hereinafter MSD) has constructed, operated and maintained the Chicago Sanitary and Ship Canal (hereinafter Canal) to date in the interests of sanitation, flood control, hydropower, and navigation; and

WHEREAS Public Law 97-377 (Further Continuing Appropriation, 1983) and the accompanying Conference Report (House Report 97-980) directed the Department of the Army (hereinafter DA) to use House Report 97-850 and Senate Report 97-673 in implementing the provisions of Public Law 97-377 and Public Law 97-88;

NOW, therefore, DA and MSD agree to the following division of responsibilities for operation and maintenance of the Canal and the Chicago River Control Structure and Lock:

1. <u>Chicago River Control Structure and Lock</u>.

a. DA agrees to operate and maintain the lock and adjoining guidewalls.

b. MSD agrees to transfer all of its right, title, and interest to the extent legally possible in the lock and its underlying lands to DA at no cost to DA.

~~c. MSD agrees that the lock shall be in operating condition at the time of transfer to DA.~~ wdg 1/15/e

c. ~~d.~~ MSD agrees to transfer all equipment associated with the lock, either at the lock or elsewhere, to DA at no cost to DA. This equipment is to be stored at the lock site storage buildings.

d. MSD agrees to provide a listing of all such equipment, showing the condition of such equipment at the time of transfer.

e. MSD agrees to operate and maintain both control structures, including the sluice gates, sluice gate machinery, and appurtenant parts at no cost to DA.

2. MSD Control Room.

MSD agrees to operate and maintain the control room without financial participation of DA.

3. Canal Banks, Levees, and Retaining Walls.

DA agrees to maintain the canal banks, levees, and retaining walls, which are defined as follows: on the left descending bank, upstream of river mile 293.1 (Butterfly Dam); on the right descending bank, upstream of the southern-most sluice gate of the Lockport Controlling Works; and on both banks, upstream to Damen Avenue.

4. Butterfly Dam.

DA agrees to remove the Butterfly Dam as part of the implementation of the Lockport Lock Major Rehabilitation Project.

5. Drift and Debris Removal.

DA agrees to perform drift and debris removal in similar fashion to the rest of the Illinois Waterway and other navigation channels throughout the country; that is, to remove materials deemed by DA to be hazardous to navigation.

6. Lockport Controlling Works and Dolphins.

a. MSD agrees to operate at no cost to DA, the Lockport Controlling Works and to operate and maintain the gates, seals, and machinery of the controlling works.

b. DA agrees to maintain at no cost to MSD, the foundation and piers of the Lockport Controlling Works.

c. DA agrees to maintain at no cost to MSD, the dolphins at the Lockport Controlling Works.

7. Lockport Dam and Powerhouse.

a. MSD will continue to operate and maintain the Lockport powerhouse and generating machinery at no cost to DA.

b. MSD agrees to operate and maintain at no cost to DA, the trash racks, gates, seals, and machinery within or attached to the concrete gravity structure. The fender wall will be maintained or removed at MSD's discretion.

c. MSD agrees to operate and maintain at no cost to DA, the superstructure and machinery therein.

d. DA agrees to operate and maintain at no cost to MSD, the currently used Lockport Lock, the remainder of the gravity structure, the cutoff wall, the right descending embankment from the gravity structure upstream to the southern-most sluice gate of the Lockport Controlling Works, and the left descending embankment and access road from the gravity structure upstream to river mile 293.1.

e. MSD agrees to maintain at no cost to DA, the access road and appurtenances on the right descending embankment of the dam at its discretion.

f. DA agrees to provide sufficient width for a roadway with a nominal width of 20 feet on the right descending embankment between the concrete gravity structure and river mile 292.2 (16th Street), as long as the roadway is maintained by MSD.

8. Bridges.

MSD agrees that DA shall not hereby assume any responsibility or obligation to operate or maintain the bridges which cross the Canal.

9. General.

a. Obligations of lessees of MSD with respect to rights-of-entry, maintenance of canal banks and restrictions on construction of structures as they may affect the canal shall accrue to DA to the extent possible under the terms of the leases and statutory constraints.

b. MSD and DA hereby convey to each other, at no cost, all rights of entry and/or easements necessary for each to carry out its responsibilities under this agreement.

c. MSD agrees to provide to DA the following for all items covered by this agreement:

(1) Operation and maintenance manuals;

(2) As-built drawings and files;

(3) Copies of all contracts with entities servicing the canal and Chicago Lock;

(4) Copies of all other agreements between MSD and other agencies which pertain to the Canal and Chicago Lock.

d. This agreement does not restrict MSD's use of, or access to, its properties or impose any additional obligations upon MSD or DA other than those contained in the agreement.

e. This agreement does not obligate MSD to continue power generation.

f. Future operation and maintenance of the Canal and Chicago Lock by DA as contained in this agreement is subject to the appropriation of funds by the Congress.

g.*

10. Effective Date.

This agreement shall take effect no later than within 90 days after signature by both parties.

William R. Gianelli
Assistant Secretary of the Army for Civil Works

MSD James C. Kirie
Chairman of the Committee of Finance

Attest:

Clerk, Gus G. Sciacqua

wrb 1/13/84

*g. Operating experience for a period in excess of forty years has demonstrated complete compatibility of interests. MSD and the Corps will continue to cooperate and will develop an operating agreement to assure balanced operating procedures benefitting all project purposes.

CHICAGO RIVER CONTROLLING WORKS: DISCHARGE RATING CURVES FOR HYDRAULIC STRUTURES

EXHIBIT G

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Chicago River Controlling Works: Discharge Rating Curves for Hydraulic Structures Obtained Through 3D CFD Simulations

Su Jin Kim[1]
Andrew R. Waratuke[2]
Jose M. Mier[3]
Marcelo H. García[4]

[1]Post-Doctoral Research Associate
[2]Research Engineer
[3]Graduate Research Assistant
[4]Professor & Director, Ven Te Chow Hydrosystems Laboratory

Sponsored by:
US Army Corps of Engineers

Ven Te Chow Hydrosystems Laboratory
Dept. of Civil and Envir. Engineering
University of Illinois
Urbana, Illinois

July 2014

Chicago River Controlling Works: Discharge Rating Curves for Hydraulic Structures Obtained Through 3D CFD Simulations

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July 2014

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1 Introduction

As a part of the Chicago Area Waterway System (CAWS), the Chicago River has an important role in flood risk management for the Chicago metropolitan area. Water levels in the Chicago River can be lowered during intense rainfall events in order to minimize backwater effects on tributary streams, thereby minimizing upstream flooding. Water levels in the Chicago River can be adjusted by operating a series of control structures located throughout the system. These structures include eight sluice gates and the navigation lock gates at the Chicago River Controlling Works (CRCW) on the Chicago River at Chicago Harbor (Figure 1.1); the sluice gates on the Chicago Sanitary and Ship Canal in Lockport, Illinois; and the sluice gates on the North Shore Channel in Wilmette, Illinois. Of particular interest is a characterization of the total volume of water and the maximum volumetric flow rate that can pass from the Chicago River into Lake Michigan via CRCW. This location is close to downtown Chicago where the potential for flood damage can be significant. Additionally, the Chicago River flows into Lake Michigan in close proximity to the drinking water intakes for the City of Chicago. This poses a potential contamination risk in the event that combined sewer overflows (CSOs) that occur in CAWS reach Lake Michigan during back flow events.

Previously, CAWS had been investigated using a three-dimensional numerical model (Shinha et al. (2012)) to characterize flow conditions and contaminant transport during wet-weather events. At that time the conveyance capacity of the sluice gates and lock at CRCW were not well known; the only available equation estimated flow through a single sluice gate and could not adequately account for the influence of multiple sluice gates operating simultaneously or the effect of the navigation lock gates, when open. Therefore, development of a method to more accurately estimate flow discharge through the sluice gate and lock structures at the mouth of Chicago River has become important for flood risk management.

The main objective of the current study is to develop discharge rating curves for the sluice gates and the navigation lock at CRCW. To obtain these curves, several flood scenarios were investigated using 3-Dimensional Computational Fluid Dynamics (3D-CFD) simulations. For this purpose, a representation of the physical geometry that includes portions of the Chicago River, Lake Michigan, and the hydraulic structures was developed and used as the computational domain with various boundary conditions. The modeling results were used to construct a discharge rating curve for the structures. Additionally, another set of numerical simulations were performed to determine the effect of fish screens on energy losses through the sluice gates (Baines and Peterson, 1951).

The overall procedures for this study are detailed as follows:

- Estimate the maximum flow that can be conveyed in the Chicago River for the one-mile reach adjacent to Lake Michigan during a backflow event
- Estimate the maximum flow capacity of the controlling structures (the sluice gates and lock at CRCW)

Figure 1.1: The satellite picture of research site
(CRCW: Chicago River Controlling Works) and four USGS stream-gaging stations: (1) North Branch Chicago River at Grand Avenue, (2) Chicago River at Columbus Drive, (3) Chicago River at Chicago Lock, and (4) Lake Michigan at Chicago Lock. (Courtesy Google Map)

during a backflow event

- Develop a discharge rating curve for each individual hydraulic structure
- Perform an analytical and numerical analysis to determine the effect of fish screens on the discharge rating curves for the sluice gates.

To better understand the hydraulics and fluid dynamics at CRCW, flow patterns occurring in the vicinity of the sluice gates and lock are investigated and visualized.

2 Numerical Framework

In this study three different numerical codes are employed to investigate the discharge ratings of the hydraulic structures at CRCW and the nearby hydrodynamics during a flood event. All three of the codes solve the three-dimensional Navier-Stokes equations and are based on the Reynolds-Averaged Navier-Stokes (RANS) approach.

2.1 Fluent

The ”Volume of Fluid” (VOF) method (Hirt and Nichols, 1981) accompanied by the standard $k-\epsilon$ turbulence model was implemented to simulate the free-surface flow on an unstructured grid. The VOF method can model two or more immiscible fluids by solving a single set of momentum equations and tracking the volume fraction of each of the fluids throughout the domain. Typical applications include the prediction of jet breakup, the motion of large bubbles in liquid, the motion of liquid after a dam break, and the tracking of any liquid-gas interface. The VOF method relies on the assumption that two or more fluids (or phases) are immischible, and therefore do not mix. For each additional phase that is added to the model, an extra variable is introduced – the volume fraction of the additional phase in the computational cell. In each control volume, the volume fractions of all phases sum to unity. The fields for all variables and properties are shared by the phases and represent volume-averaged values as long as the volume fraction of each of the phases is known at each location. Thus, the variables and properties in any given cell are either purely representative of one of the phases, or representative of a mixture of the phases, depending upon the volume fraction values. In other words, if the q^{th} fluid's volume fraction in the cell is denoted as α_q, then the following three conditions are possible:

1. $\alpha_q = 0$: The cell is empty (of the q^{th} fluid).
2. α_q = 1 : The cell is full (of the q^{th} fluid).

3. $0 < \alpha_q < 1$: The cell contains the interface between the q^{th} fluid and one or more other fluids.

Based on the local value of α_q, the appropriate properties and variables are assigned to each control volume within the domain. For the open-channel simulations of CRCW, the two phases are air and water with the Volume Fraction (VF) representing the amount of the total control volume that contains water. Because the VF is a bulk parameter for each control volume (i.e., computational cell), interpolation must be used to develop iso-surfaces to represent the free surface. A control volume with a VF = 0.5 means that half the volume is water and half is air, indicating that the free surface occurs somewhere within the control volume. Experience has shown that interpolating the Volume Fraction such that the iso-surface is drawn at VF = 0.65 does an acceptable job of identifying the free-surface location.

The ”Pressure Implicit with Splitting of Operators” algorithm (PISO) couples the pressure to the velocity field and the standard $k - \epsilon$ turbulence closure approximates the Reynolds Stresses appearing in the RANS formulation of the Navier-Stokes equations. A first-order upwind scheme is employed for spatial discretization.

2.2 Flow-3D

Flow-3D is a widely used CFD package capable of modeling free-surface flows. It provides multi-block gridding with nested and linked blocks. With this capability it is possible to vary the grid resolution locally, making it suitable for open-channel systems with large, complicated modeling domains.

2.3 SSIIM

The turbulent flow through and around a fish screen located on the riverward side of the sluice gates was calculated using the RANS model SSIIM (Sediment Simulation In Intakes with Multiblock option). SSIIM solves the RANS equations on a Cartesian grid using a finite volume scheme (Fischer-Antze et al., 2001 and Pope, 2000). The convective term in the RANS equations is approximated with a second order upwind scheme, while the diffusive term is approximated with a second order central differencing scheme. The pressure term is calculated by an iterative procedure based on the SIMPLE algorithm (Pantankar, 1980). The Reynolds stress term in the equation requires a suitable closure model. The eddy-viscosity concept is introduced with the Boussinesq approximation to model the Reynolds stress term. The turbulent eddy viscosity is determined by the standard $k - \epsilon$ turbulence model.

2.4 Model Application

Initially, Fluent was adopted to determine the discharge rating curves at CRCW. For these simulations, an assumption of a constant bed elevation at both CRCW and Lake Michigan was made, resulting in a high degree of numerical stability and rapid convergence. However, when the domain was extended to Wolf Point and the surveyed river bathymetry was incorporated, the increased geometric complexity presented difficulties when generating the computational mesh and resulted in numerical instabilities and poor convergence in Fluent. These issues prompted a switch to Flow-3D.

The large difference in geometric scale between the bars on the fish screen and the rest of the model geometry made it impractical to model the fish screens directly. Instead, a porosity approach was used in which the screens were modeled as porous surfaces with similar discharge characteristics to the actual screens. The effective porosity parameters were determined using SSIIM. Once the parameters had been determined, the sluice gates with the porous screens were modeled in Fluent to determine the effect of flow interaction on the discharge characteristics. Table 2.1 summarizes the three CFD modeling packages and their applications as used for the current study.

Table 2.1: Summary of CFD models adopted for the study

Model	Modeled Domain and Intended Application	Boundary Conditions	Assumptions and Limitations
Flow-3D	Chicago River and CRCW (from Wolf Point to Lake Michigan)	Inlet: flowrate Outlet: constant water level in Lake Michigan	- Strength on varying topography in an open-channel like Chicago River - Real topography is used
Fluent	Rating curves at CRCW (from Columbus Drive to Lake Michigan)	Inlet: flowrate Outlet: constant water level in Lake Michigan	- Varying topography gives less stability - A constant bottom is assumed
	Fish screen at sluice gates with porosity approach	Inlet: flowrate Outlet: constant water level in Lake Michigan	- Free surface calculation is available - Difficulties on input parameters for porosity approach
SSIIM	Fish screen at sluice gates with porosity approach	Inlet: flowrate Outlet: constant water depth for both river and lake	- Free surface calculation is not available - Simple parameter is used porosity approach

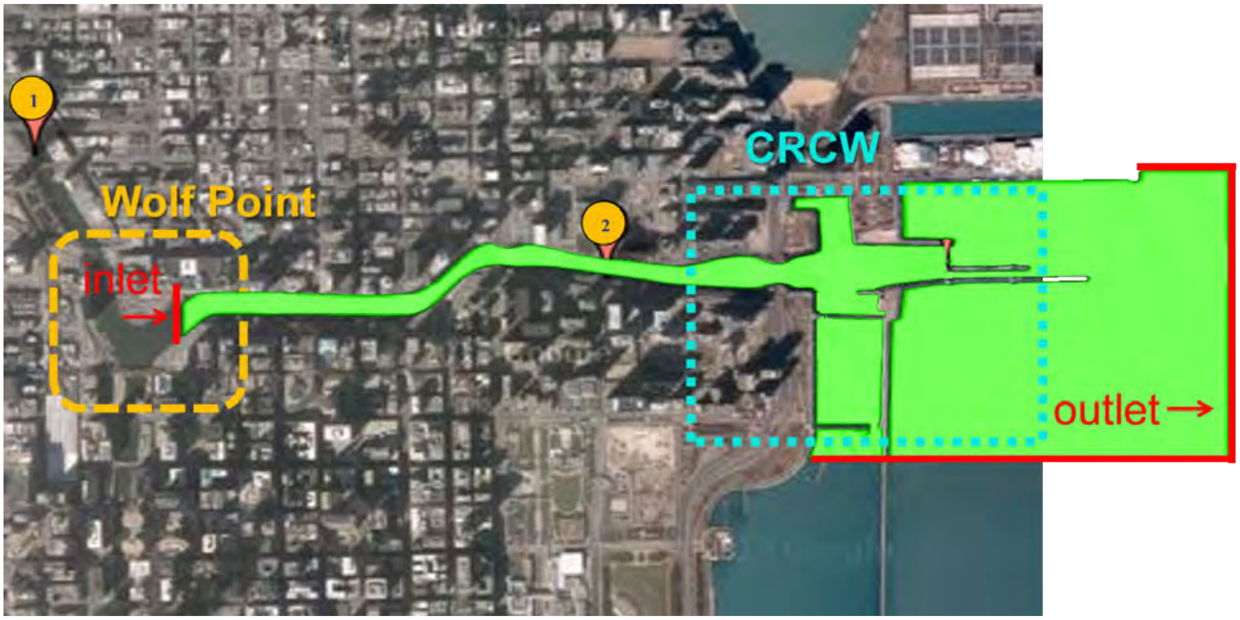


Figure 3.1: The numerical domain from the Wolf point (inlet) to the Lake Michigan (outlet)

3 Maximum Flow Through the Chicago River

The water level in Lake Michigan is subject to long-term and seasonal variations; however, the water levels on CAWS are controlled through the waterway operations of the Metropolitan Water Reclamation District of Greater Chicago (MWRD) and the US Army Corps of Engineers (Corps). The historical lake level varies from about -3.0 to +3.0 ft CCD (the City of Chicago Datum = 579.48 ft [173.63 m] NGVD29), and it has been in the range of -3.0 to +0.5 ft CCD since August 1997 based on the measurement data from USGS stream-gaging station #04087440 (Lake Michigan at Chicago Lock at Chicago, IL). The water level on the river-ward side of CRCW is normally maintained at -2.0 ft CCD in compliance with CFR navigation regulations and it rises above the normal pool level during major rainstorm events. When the water level on the Chicago River reaches +3.0 to +3.5 ft CCD during significant rainstorm events, the sluice gates at CRCW are opened to minimize the flooding potential in CAWS by releasing excess floodwater into Lake Michigan. In the event that water levels in the river continue to rise after the sluice gates have been opened, the navigation lock gates are opened as well.

Accordingly, it is important to develop a rating curve to estimate the discharge through each hydraulic structure for a given water level at CRCW. The total flow capacity of the system may differ from the combined capacity of the sluice gates and navigation lock gates, however. The total capacity may be limited by the hydraulic conveyance of the Chicago River channel upstream of CRCW. Therefore, the current numerical study was performed to estimate the maximum flow discharge through the Chicago River as well as the maximum capacity of the flow through the hydraulic structures.

3.1 Simulation Setup and Boundary Conditions

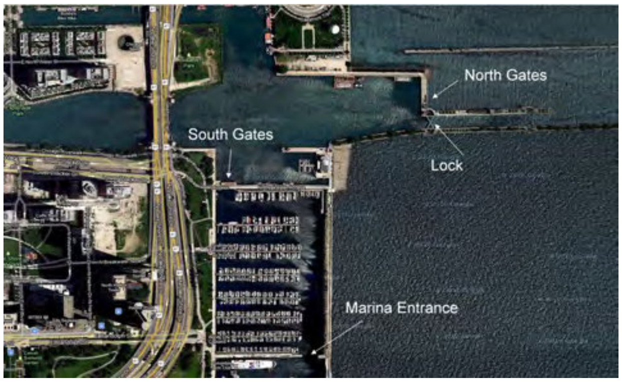
Flow-3D was chosen to perform the numerical simulations for the Chicago River from Wolf Point to Lake Michigan and the domain boundary is shown in Figure 3.1. The inlet boundary at the upstream end of the model is located immediately east of Wolf Point (which is also the west end of the Main Branch of the Chicago River). The outlet boundary is established in Lake Michigan as shown in Figure 3.1. The actual surveyed bathymetry was used for the Chicago River while the Lake Michigan bottom is assumed to be flat with a constant elevation of -25 ft CCD. The river and lake are separated by the hydraulic structures at CRCW. A bird's-eye view of CRCW and the location of each hydraulic structure are shown in Figure 3.2a.

The Flow-3D modeling domain is composed of several block-structured Cartesian H-grids and is depicted in Figure 3.2b. The domain is divided into 16 blocks and each block is comprised of numerous cells of the same size. Since Flow-3D uses only rectilinear Cartesian mesh blocks, there will by necessity be some computational cells that lie outside of an irregularly shaped model geometry. Computationally, Flow-3D predetermines that these cells are inactive (not available to the flow) and hydrodynamic computations are not performed on them. For the CRCW modeling domain, there are a total of 4,661,185 cells with 3,183,118 actively cells.

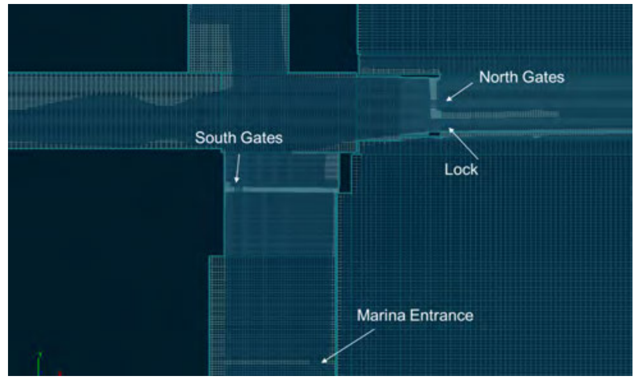
Details of the CRCW control structures are shown in Figure 3.3. The four south and four north sluice gate structures each have vertically opening gates with an opening size of 10×10 ft. The clear spacing between two adjacent gates is 4 ft. The sluice gates are located between -8 and -18 ft CCD in the vertical direction. The lock is located immediately south of the northern gates and is equipped with two sector gates on each end (east or west) of the lock chamber (Figure 3.3, right). In Figure 3.3, the river side is colored in green and the flow direction is from river to the lake (green to blue) during back-flow operation. During back-flow events, the hydraulic structures are opened as necessary in the following sequence:

1. the four south sluice gates are opened
2. the four north sluice gates are opened
3. the southern navigation lock sector gates are opened (half of the lock width is available to flow)
4. the northern navigation lock sector gates are opened (the full lock width is available to flow)

The goal of the present study is to determine the maximum discharge capacity of CRCW, expected to occur when all of the sluice gates and the navigation lock are fully open (corresponding to step 4). After completion of the aforementioned simulation runs, additional runs corresponding to the Step 3 condition were performed in order to quantify the influence of the sector gate opening position on discharge through CRCW.



(a)



(b)

Figure 3.2: (a) The location of hydraulic structures at CRCW (Courtesy Google Map) and (b) a numerical domain of it for the Flow-3D

To estimate the maximum flow conveyance of the lake-adjacent one-mile reach of the Chicago River during a back-flow event, a constant inflow in the range of 15,000 cfs to 30,000 cfs is given at inlet boundary. For the outlet boundary in the Lake Michigan, a constant water level of 0 ft CCD was applied during the simulations. The initial water level in the Chicago River at Wolf Point and Lake Michigan are assigned to be 4 ft CCD and 0 ft CCD, respectively. A no-slip boundary condition is applied to all the geometric boundaries including the channel bed and the structure walls.

3.2 Results

The maximum flow in the Chicago River is estimated by modeling a steady-like river reach with a constant flow (discharge), and the water levels at Wolf Point and CRCW are initially maintained at about 4 ft CCD and 3 ft CCD, respectively. The flow passing through the Chicago River (at Columbus Drive) and hydraulic structures (at CRCW) are monitored as are the water surface elevations at Wolf Point, Columbus Drive, CRCW, and Lake Michigan.

Modeling results indicate that the maximum flow conveyed by the Chicago River is approximately Q=28,284 cfs ($\pm$1,334 cfs) determined from the modeling results after they had converged to a steady value as shown in Figure 3.4a. Other results corresponding to the data are shown in Table 3.1 and Figure 3.5. Table 3.1 describes the averages and standard deviations of the time series, while Figure 3.5 shows the range of the results on the horizontal map. Consequently, when all sluice gates and the lock are open, the flood model is stable and shows a realistic condition until the water levels at Columbus Drive and at CRCW are about 2.77 ft CCD and 2.54 ft CCD, and the corresponding maximum flow rate through the Chicago River, lock, and all sluice gates are on average 28,284 cfs, 20,166 cfs and 8,219 cfs, respectively.

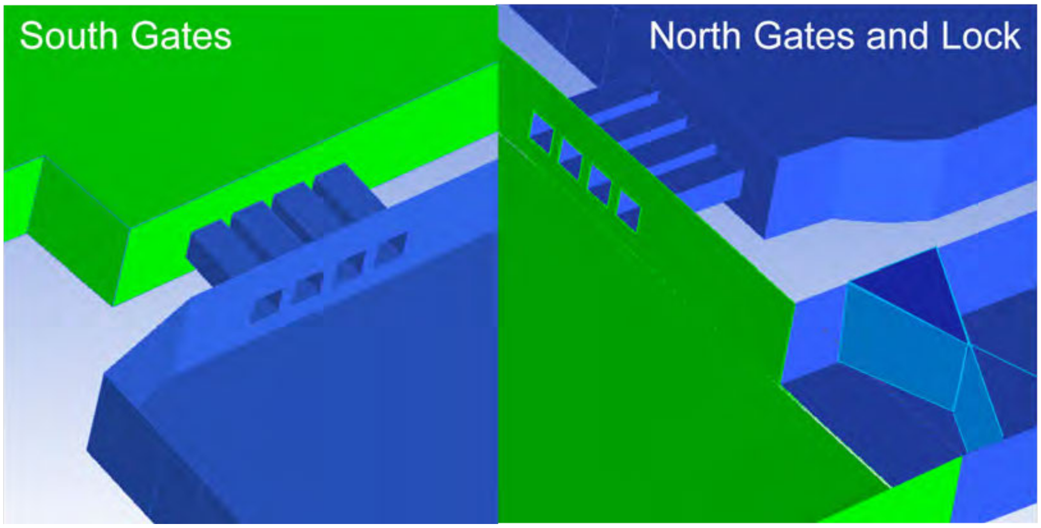


Figure 3.3: Geometry of hydraulic structures at CRCW; four south gates (left), four north gates and lock (right).

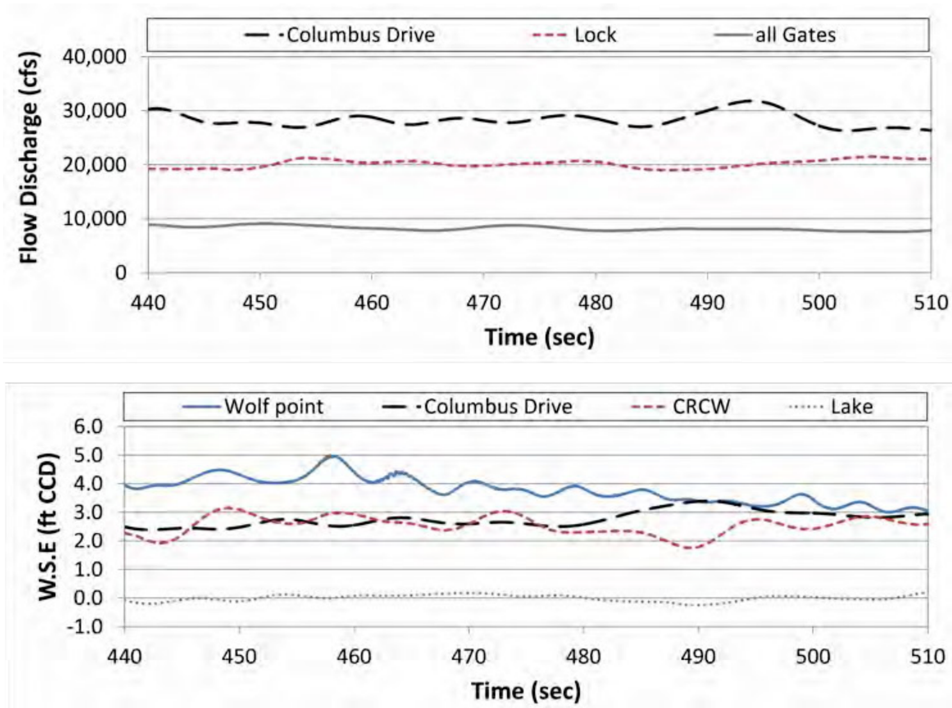
An additional simulation was performed with the lock 50% opened (southern lock-gate opens, Step 3). This resulted in a reduction in flow rate to Q=20,893 cfs ($\pm$1,044 cfs). As presented in Figure 3.4b and Table 3.1, the discharge through the sluice gates is not effected by the lock gate opening. As expected, the total discharge passed by the lock is decreased, but the decrease is only by approximately 40% (from 20,166 to 11,584 cfs for the fully open and 50% open lock, respectively).

4 Discharge Rating Curves for Hydraulic Structures

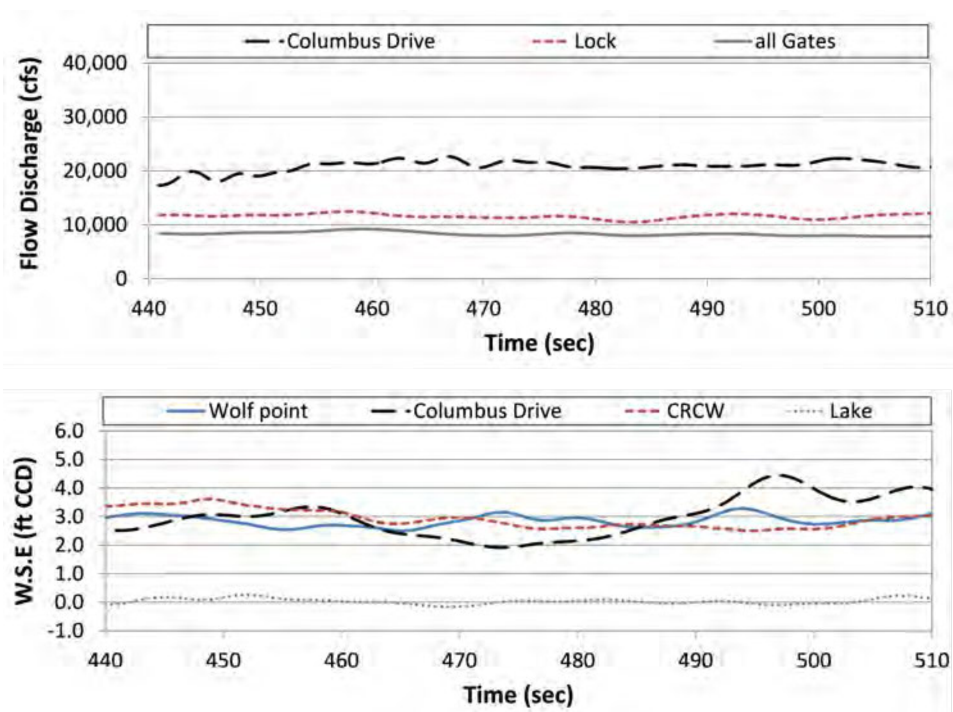
In this section, discharge rating curves for the hydraulic structures including the navigation lock are investigated using 3D-CFD simulations. For this portion of study, Fluent was employed and the results are compared with the maximum flow capacity of the hydraulic structures (sluice gates and lock) during a backflow event as estimated by Flow-3D. Additionally, plots showing the resulting velocity and turbulence patterns cause by flow through the lock chamber and sluice gates are included in Appendices A and B.

4.1 Simulation Setup and Boundary Conditions

The modeled region includes all of the hydraulic structures at CRCW including the four north-side sluice gates, four south-side sluice gates, and the lock. The numerical domain is shown in Figure 4.1. During the modeling runs gates are initially closed and are opened when the river stage increases above +3.0 ft CCD (as long as river stage $>$ lake stage). The following boundary conditions and scenarios are considered:



(a)



(b)

Figure 3.4: Timeseries of the monitored flow discharge and water level after steady-like condition at time=440sec with (a) Q=28,284 cfs ($\pm$1,334 cfs) and (b) Q=20,893 cfs ($\pm$1,044 cfs) at Columbus Drive

Table 3.1: Statistical data of the monitored maximum flow through the Chicago River

Lock Opening	Monitored Quantity	Location	Average	Standard Deviation
Fully Open	Discharge (cfs)	Columbus Drive	28,284	±1,334
		Lock	20,166	±735
		All Gates	8,219	±476
	Water Surface Elevation (ft CCD)	Wolf Point	3.78	±0.45
		Columbus Drive	2.77	±0.27
		CRCW	2.54	±0.33
		Lake Michigan	0	±0.12
50% Open	Discharge (cfs)	Columbus Drive	20,893	±1,044
		Lock	11,584	±432
		All Gates	8,315	±362
	Water Surface Elevation (ft CCD)	Wolf Point	2.85	±0.20
		Columbus Drive	2.92	±0.32
		CRCW	2.97	±0.70
		Lake Michigan	0.04	±0.10

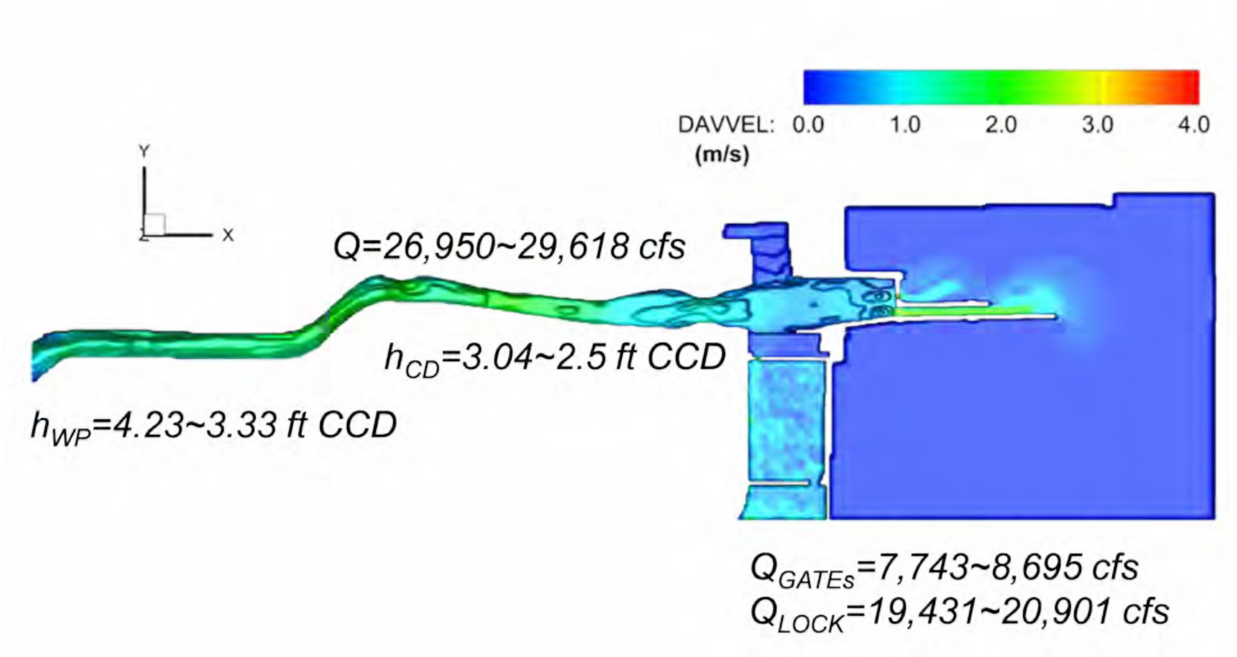


Figure 3.5: The range of the monitored maximum flow through the Chicago River

- Lake level ranges between -3 and +4 ft CCD.
- A single sluice gate open.
- All four sluice gates in a group (north or south) open.
- All eight sluice gates and the lock gate open.

Additional parameters to define a study case include the inflow at Columbus Drive (Q, cfs), the initial water level on the Chicago River and Lake Michigan ($Y_{i,river}$ and $Y_{i,lake}$, ft CCD), and the initial hydraulic head (Δh_i, ft) which is defined as Δh_i = $Y_{i,river}$ - $Y_{i,lake}$. The initial water levels on the Chicago River (1 – 4 ft CCD) and Lake Michigan (-3 – 0 ft CCD) are specified. The initial condition represents the condition prior to opening either the sluice gates and/or lock gates. The initial velocity in the entire model domain is assumed to be 0 ft/s, and the bed elevation is constant at -24.94 ft CCD. The initial water levels at the beginning of simulation and a constant inflow ranging from 5,000 – 40,000 cfs are given as the inlet boundary condition at Columbus Drive. The flow direction is from left to right in Figure 4.1. The water level on Lake Michigan is maintained constant during the simulation. A no slip boundary condition is applied at the channel bed and structure walls.

Table 4.1 summarizes the structure opening combinations that were simulated for this study. The table indicates, for example, that case C4 has only the four north-side sluice gates open and C6 is the case that all the hydraulic structures including the lock are opened during the back flow operation. Table 4.2 shows the initial water-surface elevations, flows, and final water-surface elevations (after steady-state) for several of the modeled cases, focusing on Case 6 (all sluice gates and lock gates open).

Table 4.1: Simulation matrix on the operation of hydraulic structures

	SG1	SG2	SG3	SG4	NG1	NG2	NG3	NG4	Lock
C1	○	○	○	○	○	○	○	○	
C2					○				
C3	○								
C4					○	○	○	○	
C5	○	○	○	○					
C6	○	○	○	○	○	○	○	○	○

SG = south-side sluice gate
NG = north-side sluice gate
○ = open structure

Table 4.2: Results of case study classified by inflow and initial conditions

	inflow	initial condition (ft CCD)			final condition (ft CCD)			
case	Q (cfs)	$Y_{i,river}$	$Y_{i,lake}$	Δh_i	$Y_{f,river}$	$Y_{f,innerharbor}$	$Y_{f,lake}$	Δh_f
C1-1	5000	4	0	4	0.45	-0.45	-0.52	0.97
C6-3	10000	4	0	4	0.38	0.12	0.08	0.3
C6-2	15000	4	0	4	0.67	0.08	0.04	0.63
C6-4	20000	4	0	4	1.27	0.23	0.17	1.09
C6-10	15000	1	-3	4	-2.4	-2.81	-2.95	0.6
C6-5	20000	1	-3	4	-1.75	-2.77	-2.99	1.25
C6-6	25000	1	-3	4	-1.17	-2.79	-3.02	1.82
C6-7	30000	1	-3	4	-0.26	-2.82	-3.11	2.74
C6-8	35000	1	-3	4	0.71	-2.77	-2.95	3.71
C6-9	40000	1	-3	4	1.59	-2.79	-3.07	4.59

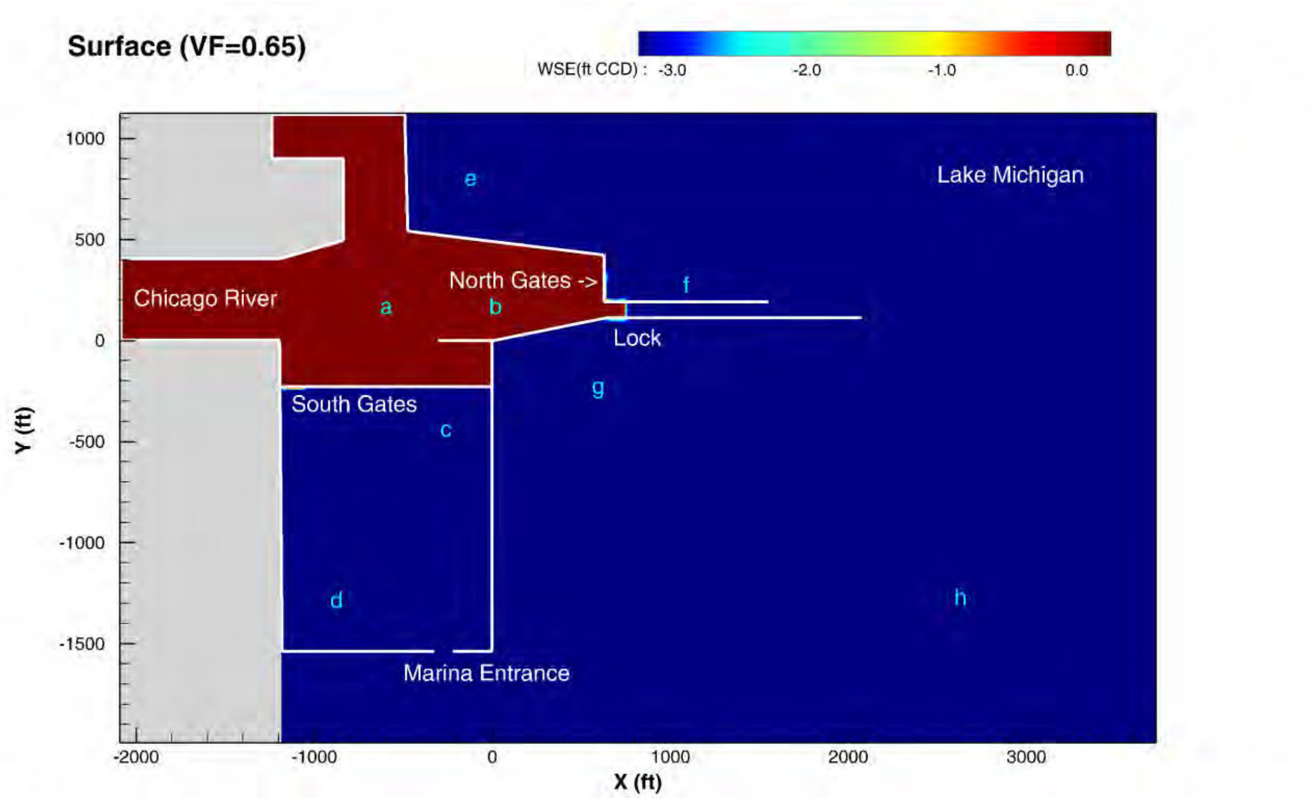


Figure 4.1: Distribution of water level of initial condition on the numerical domain

4.2 The Discharge Through Hydraulic Structures and Final Hydraulic Head (ΔH_F)

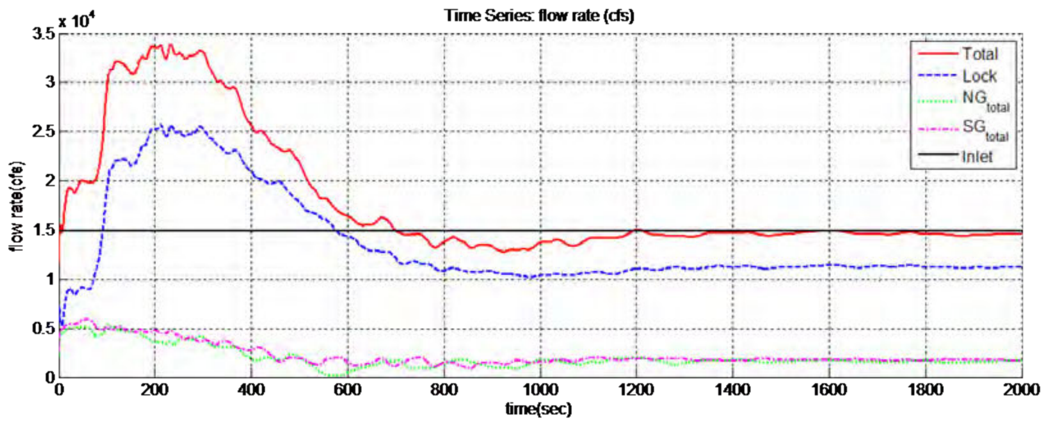
The discharge through the eight sluice gates and lock is monitored by establishing virtual flux surfaces within the model. These surfaces are used to monitor time-dependent fluid flow rates and other flow properties such as velocities and flow depth at specified locations.

The time-series of flow and stage for Case C6-2 (inflow = 15,000 cfs) are plotted in Figure 4.2. This figure shows that the flow rate through the control structures stabilizes and becomes steady after about 1200 seconds (Figure 4.2a). Flow rates for each case are determined from an average of the time period from 1500 to 2000 sec.

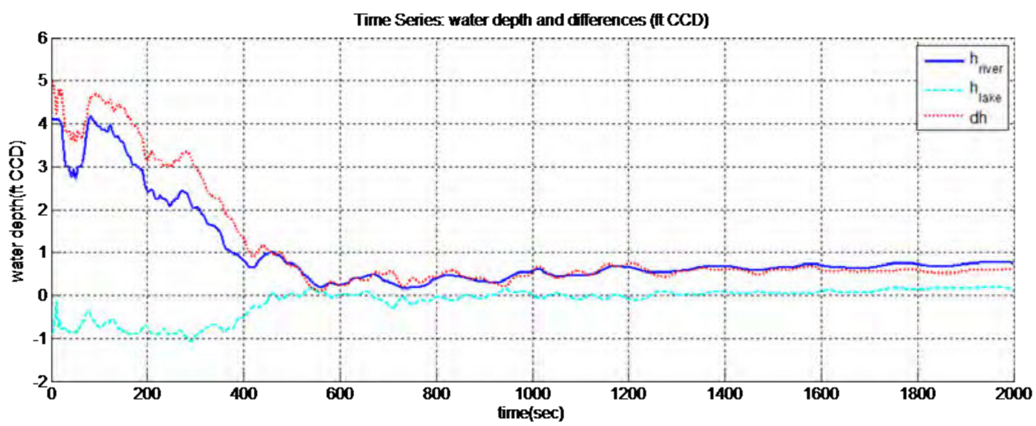
For all of the case C6 model runs (with all of the structures open), the average discharge through the lock during flood constitutes 75.1–76.8% of the total outflow. The sluice gate groupings pass 11.7% and 12.6% of the total outflow through the north-side sluices and south-side sluices, respectively. The difference in flow between the northern and southern sluice gates is small ($\sim 1\%$ of the total flow), but in all cases, more flow passes through the southern sluice gate group. That is, about 48.1% and 51.9% of the total sluice-gate flow is contributed by the north-side gates and south-side gates, respectively. On the other hand, for the case C1 model runs (all sluice gates open and the lock closed) the total amount of flow through the north-side gates (52.1%) is larger than that through the south-side gates (47.9%). This result indicates that the state of the lock gates (open vs. closed) has an effect on the flow distribution of the sluice gates, demonstrating an apparent flow interaction between the lock and the north-side gate group (the south-side gates are not expected to be effected due to the distance from the lock).

Velocity contour plots were generated at times t = 1, 50, 500, and 1000 seconds for a plan-view ($x - y$ plane) cross section located at the mid-depth of the sluice gates ($z = -13$ ft, -4.1 m) and at the water surface for case C6-2 (Figure 4.3). Longitudinal plots showing the water-surface elevation and velocity contours are also plotted for two north-side sluice gates, two south-side sluice gates and the lock. The time evolution of the velocity distributions indicate that a steady condition is reached after about 1000 sec.

The flow rate and water surface elevation at each of eight selected locations (labeled (a)–(h) in Figure 4.1) are extracted at one second intervals for the time period from 0 to 2000 seconds. Locations (a) and (b) are selected as representative of water level in the Chicago River, locations (c) and (d) for the inner harbor, and locations (e) – (h) for Lake Michigan. The time series are spatially averaged, and then the water levels in the Chicago River and the Lake Michigan are plotted for case C6-2 (inflow = 15,000 cfs) in Figure 4.2b. The hydraulic head (the difference between the water levels in the Chicago River and Lake Michigan) is also calculated and plotted. Water levels appear to stabilize and reach a steady condition after 1200 sec. Therefore, the final water-surface elevations used in the calculation of the discharge coefficients is determined as the temporal average at each location over the time period from 1500 – 2000 seconds.

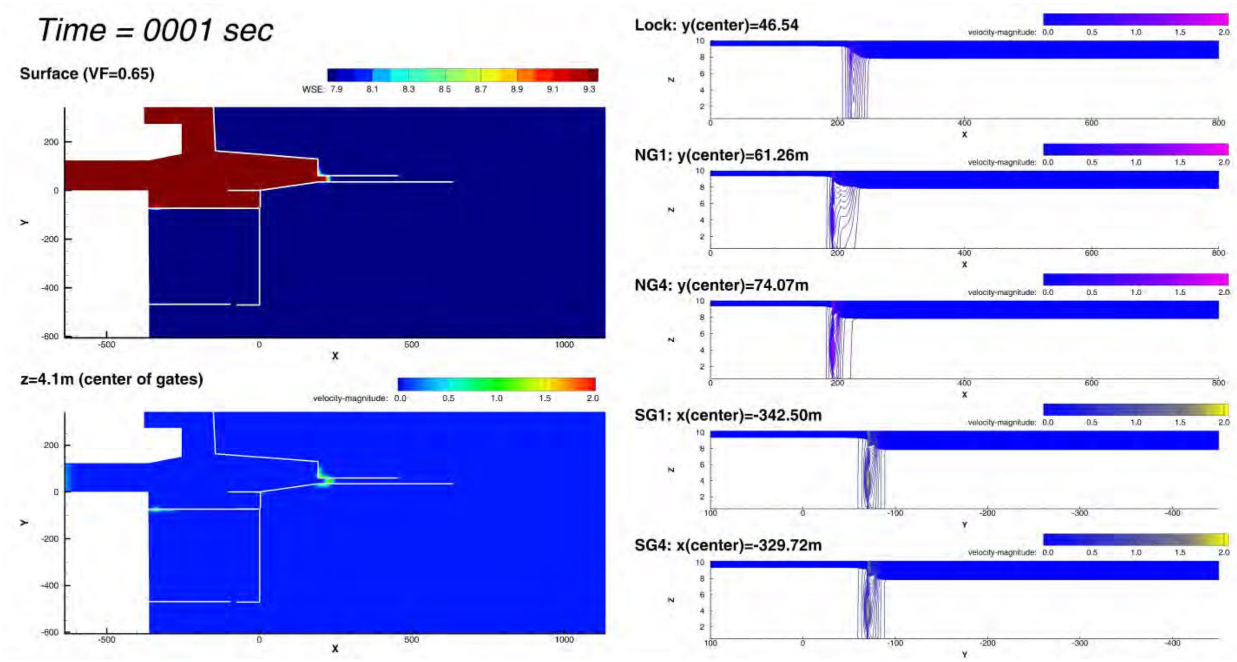


(a)

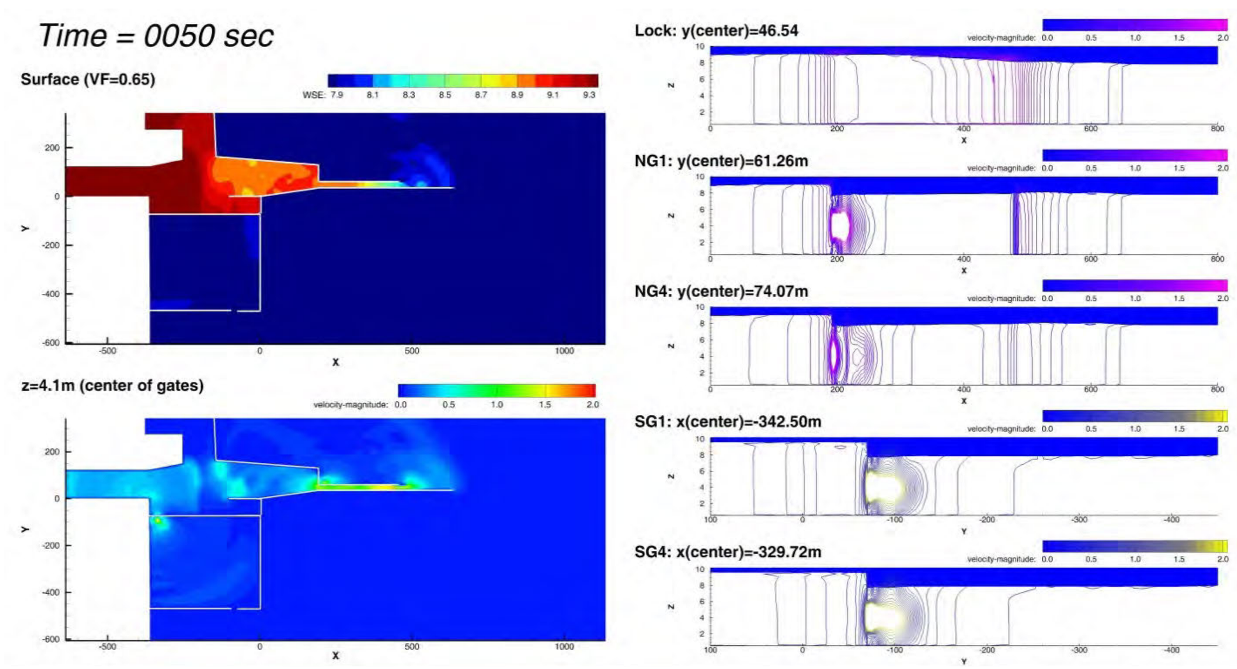


(b)

Figure 4.2: Timeseries of (a) discharge through structures and (b) water levels (ft CCD) and hydraulic head of C6-2 case (15,000 cfs)

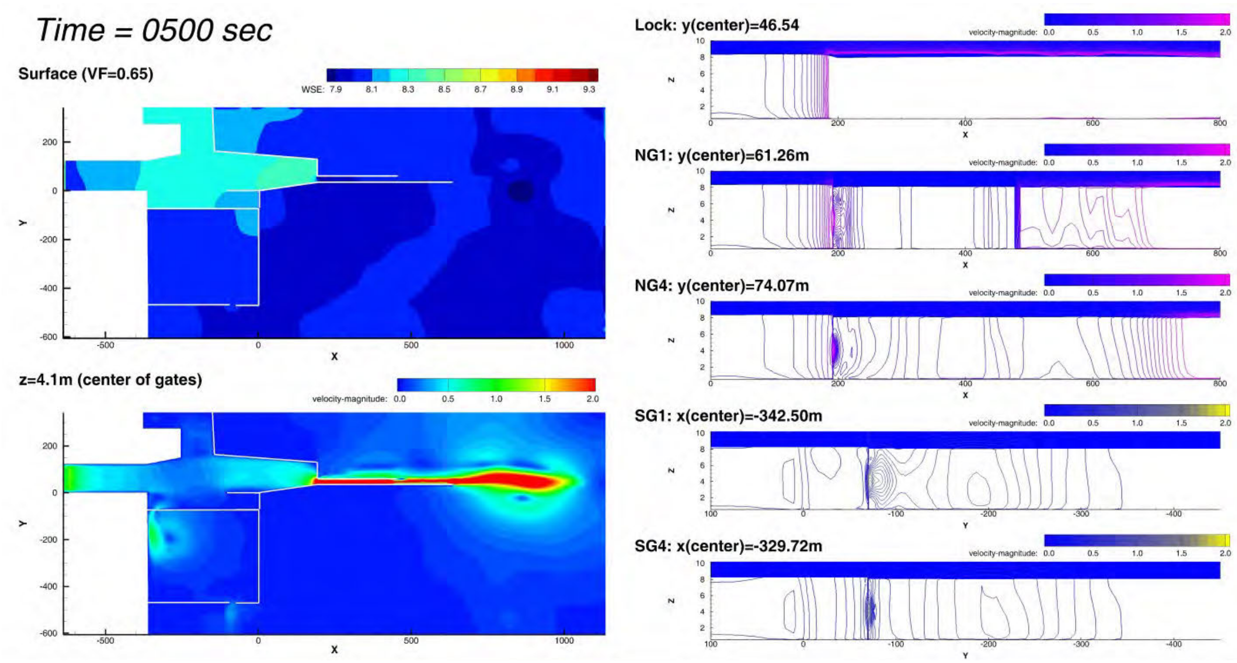


(a)



(b)

Figure 4.3: Water level and velocity distribution at the height of middle of sluice gates (z =-13 ft or -4.1 m) in $x - y$ plane (left) and contour of velocity distribution with water level in $x - z$ plane at (a) 1 sec, (b) 50 sec, (c) 500 sec, and (d) 1000 sec



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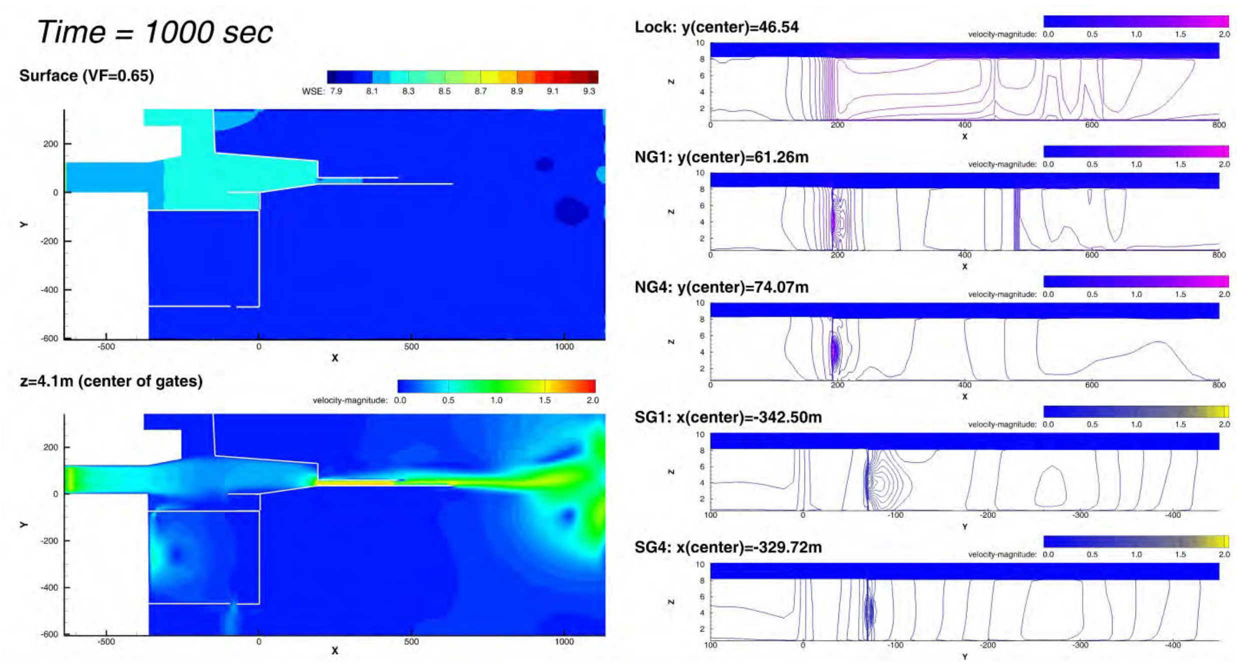


(d)

Figure 4.3: Water level and velocity distribution at the height of middle of sluice gates ($z =$-13 ft or -4.1 m) in $x - y$ plane (left) and contour of velocity distribution with water level in $x - z$ plane at (a) 1 sec, (b) 50 sec, (c) 500 sec, and (d) 1000 sec

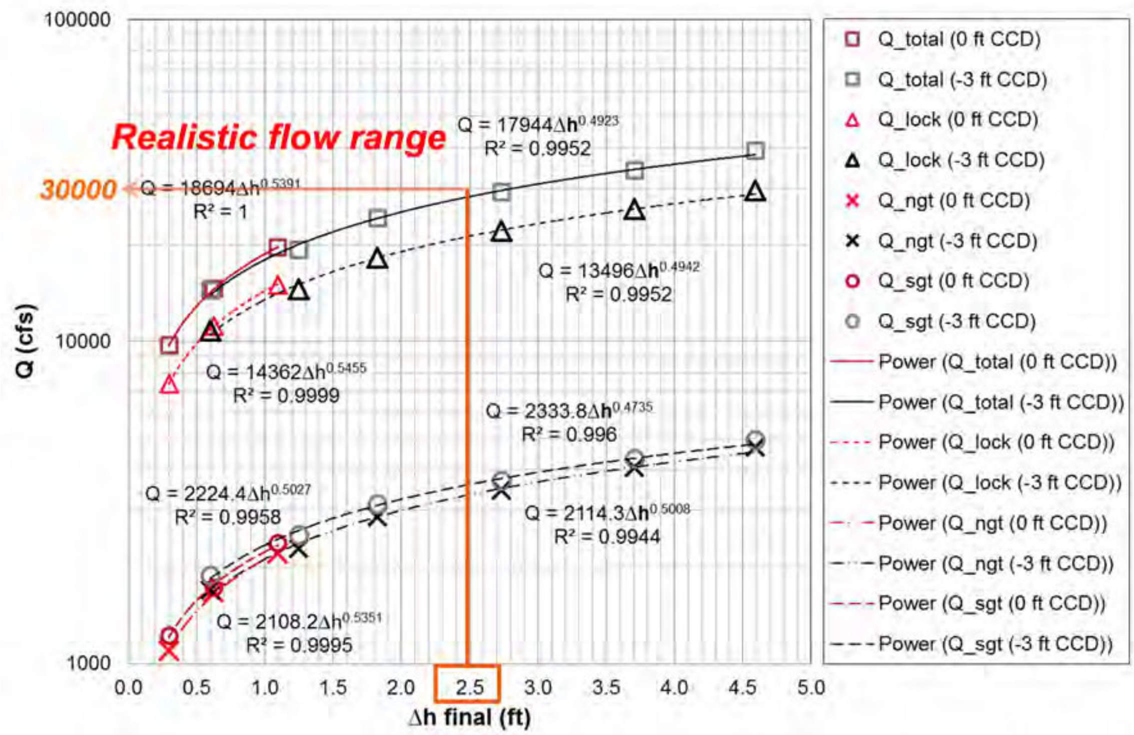


Figure 4.4: Rating curves with power regression analysis for total outflow through all structures (square), outflow through lock (triangle), outflow through 4 north gates (cross), and outflow through 4 south gates (circle)

4.3 The Effect of Initial Water Level in Lake Michigan ($\mathbf{Y}_{i,lake}$) on Discharge Through the Gates

Figures 4.4, 4.5 and 4.6 present the CFD-determined relationship between flow rate (Q) and final hydraulic head (Δh_f) for the control structures. The results from all the simulations collapse closely and seem to follow a definitive trend. Therefore, the rating curves for each initial water level in Lake Michigan (0 ft and -3 ft CCD) are analyzed with power-law regression relationship. All of the rating curves fitted to the simulation results have a similar power-law equation of the following form:

$$Q = K\Delta h_f^b \tag{4.1}$$

Most often, discharge relationships for gates are presented in terms of the area of the gate, A, the gravitational acceleration, g, the head, Δh, and a discharge coefficient C.

$$Q = CA\left(2g\Delta h_f\right)^b \tag{4.2}$$

Table 4.3: Fitted K, b, and discharge Coefficient for equations (4.1) and (4.2)

	Q	K	b	Area (ft^2)	Coefficient
Y_{lake}=0 ft CCD	Q_{total}	18694	0.5391		
	Q_{lock}	14362	0.5455		
	Q_{ngt}	2108	0.5351	400	0.57
	Q_{sgt}	2224	0.5027	400	0.69
	Q_{NG1}	524	0.5278	100	0.58
	Q_{NG2}	541	0.5329	100	0.59
	Q_{NG3}	536	0.5345	100	0.58
	Q_{NG4}	507	0.5457	100	0.52
	Ave$_{NG}$	527	0.5352		0.57
	STD$_{NG}$	15	0.0075		0.03
	Q_{SG1}	536	0.5093	100	0.64
	Q_{SG2}	573	0.5013	100	0.71
	Q_{SG3}	564	0.4987	100	0.71
	Q_{SG4}	551	0.5018	100	0.68
	Ave$_{SG}$	556	0.5028		0.69
	STD$_{SG}$	16	0.0046		0.03
Y_{lake}=-3 ft CCD	Q_{total}	17944	0.4923		
	Q_{lock}	13496	0.4942		
	Q_{ngt}	2114	0.5008	400	0.66
	Q_{sgt}	2334	0.4735	400	0.81
	Q_{NG1}	527	0.5005	100	0.66
	Q_{NG2}	549	0.4993	100	0.69
	Q_{NG3}	538	0.4968	100	0.68
	Q_{NG4}	500	0.5071	100	0.6
	Ave$_{NG}$	529	0.5009		0.66
	STD$_{NG}$	21	0.0044		0.04
	Q_{SG1}	557	0.4813	100	0.75
	Q_{SG2}	602	0.4716	100	0.85
	Q_{SG3}	594	0.4702	100	0.84
	Q_{SG4}	580	0.4713	100	0.82
	Ave$_{SG}$	583	0.4736		0.81
	STD$_{SG}$	20	0.0052		0.04

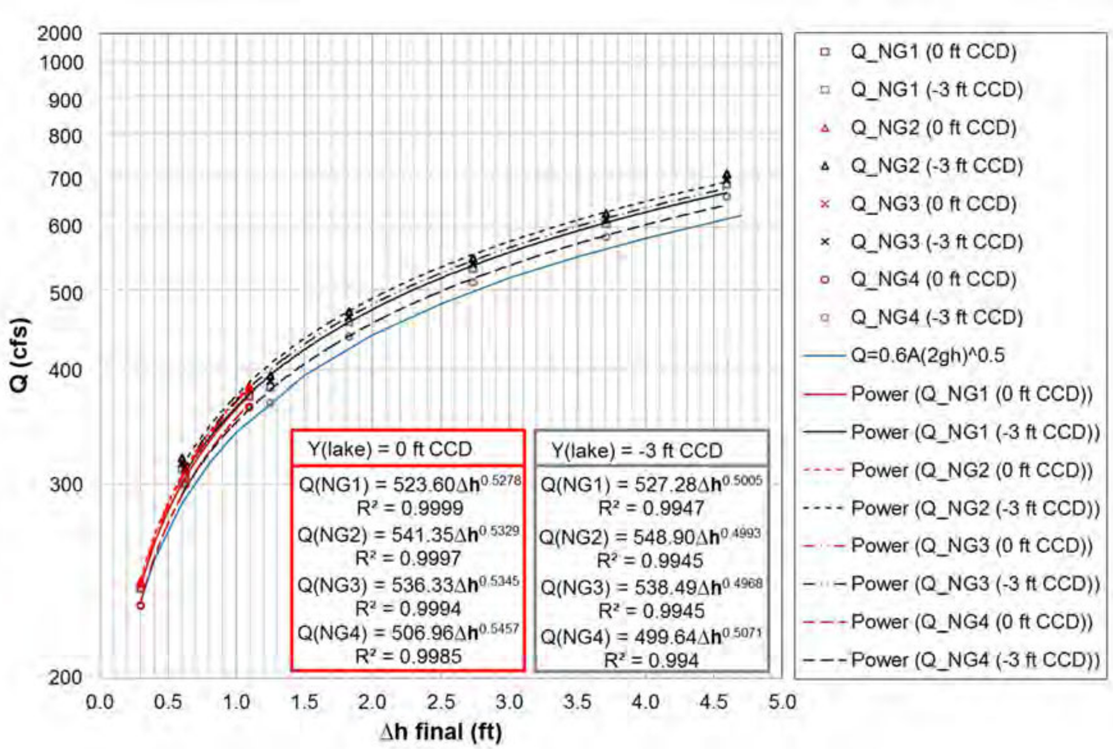


Figure 4.5: Rating curves with power regression analysis for outflow through each north-side sluice gate

This equation is a similar to the formula ($Q = 0.6A(2g\Delta h_f)^{0.5}$) currently used by engineers to calculate the flow diversion from Lake Michigan (plotted in Figures 4.5 and 4.6 with a blue solid line). In this formula, area, A, depends on the width and height of the gate. In all of the present simulations the gates are fully submerged and 100% open resulting in an area of 100 ft^2 for the 10$\times$10-ft gates.

Based on the CFD results, the discharge coefficient, C, ranges from 0.52–0.59 for the north sluice gates and 0.64–0.71 for the south gates. Based on equations (4.1) and (4.2), parameters K, b, and C are fitted or calculated for each hydraulic structure at CRCW, and the results are listed in Table 4.3 and plotted in Figure 4.7. The blue horizontal lines in Figure 4.7 indicate the the parameter values from the formula currently used to calculate the flow diversion from Lake Michigan ($Q = 0.6A(2g\Delta h_f)^{0.5}$). The results also show that the values of these parameters are dependent on the water level in Lake Michigan (0 ft and -3 ft CCD). For example, the discharge coefficient increases as the water level in Lake Michigan decreases regardless of the location of the gates. The power-law exponent, b, found from the discharge ratings ranges from 0.47 – 0.54 for the gates in CRCW. This is similar to the discharge formula for the submerged orifice flow which has a power of 0.5. Water levels in Lake Michigan also effect this exponent with the value decreasing as water-levels in the Lake decrease.

The average and standard deviation of these parameters for each group of gates: the four north gates and four south gates, are calculated. These group averages tend to be larger than the value of 0.6 used presently for

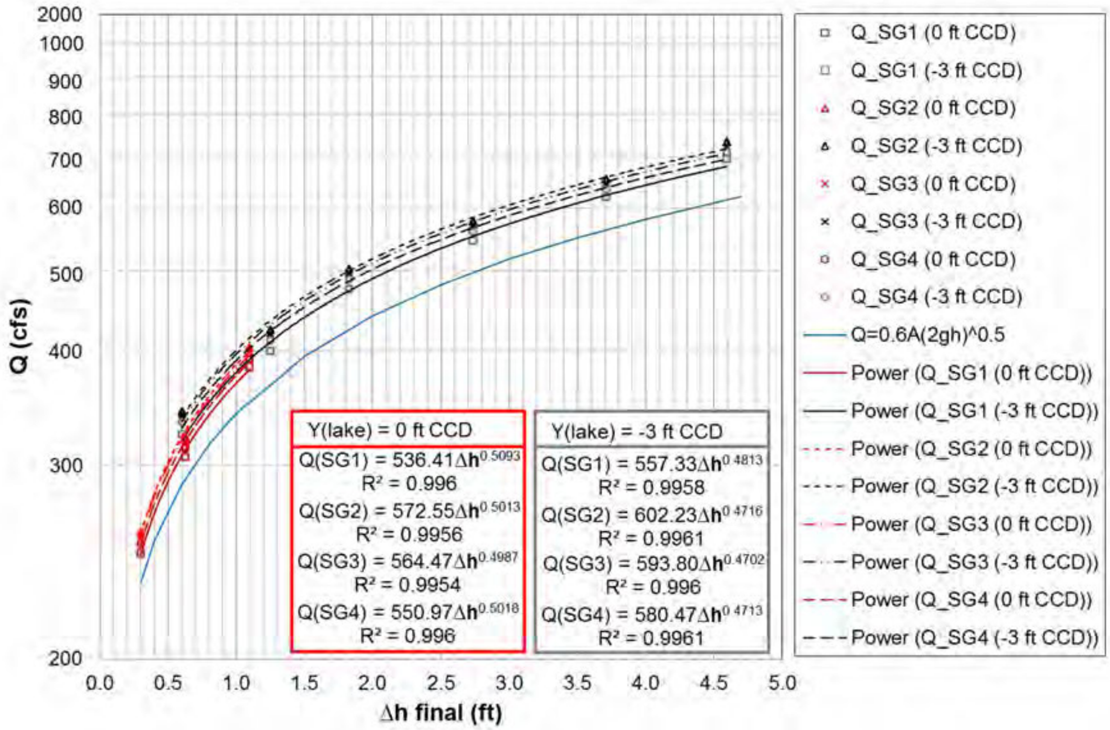


Figure 4.6: Rating curves with power regression analysis for outflow through each south-side sluice gate

Lake Michigan diversion accounting and this difference increases as Lake Michigan water-levels decrease.

The time series of flow rate for two cases are plotted in Figures 4.8 and 4.9. Both cases are performed with the same inflow condition of 20,000 cfs, but the initial water levels are 0 ft CCD and -3 ft CCD for Figure 4.8 and Figure 4.9, respectively. Comparing the flow rate through the hydraulic structures, it is found that the case with $Y_{i,lake}$ =0 ft CCD has a higher peak discharge; for example, the peak flow rate thorough the lock is about 27,000 cfs for the C6-4 case for which $Y_{i,lake}$ =0 ft CCD while the rate is 23,000 cfs for the C6-5 case for which $Y_{i,lake} = -3$ft CCD. Moreover, the final flow rates in the steady condition also change with initial water level in Lake Michigan.

As discussed previously, the maximum capacity of flow through the Chicago River was estimated at 30,000 cfs, greater than the total capacity of the CRCW control structures. This means that any discharge over 30,000 cfs through the Chicago River could result in possible Downtown flooding as it is possible to convey more discharge to the control structures at CRCW than they are able to release into Lake Michigan, even when completely open.

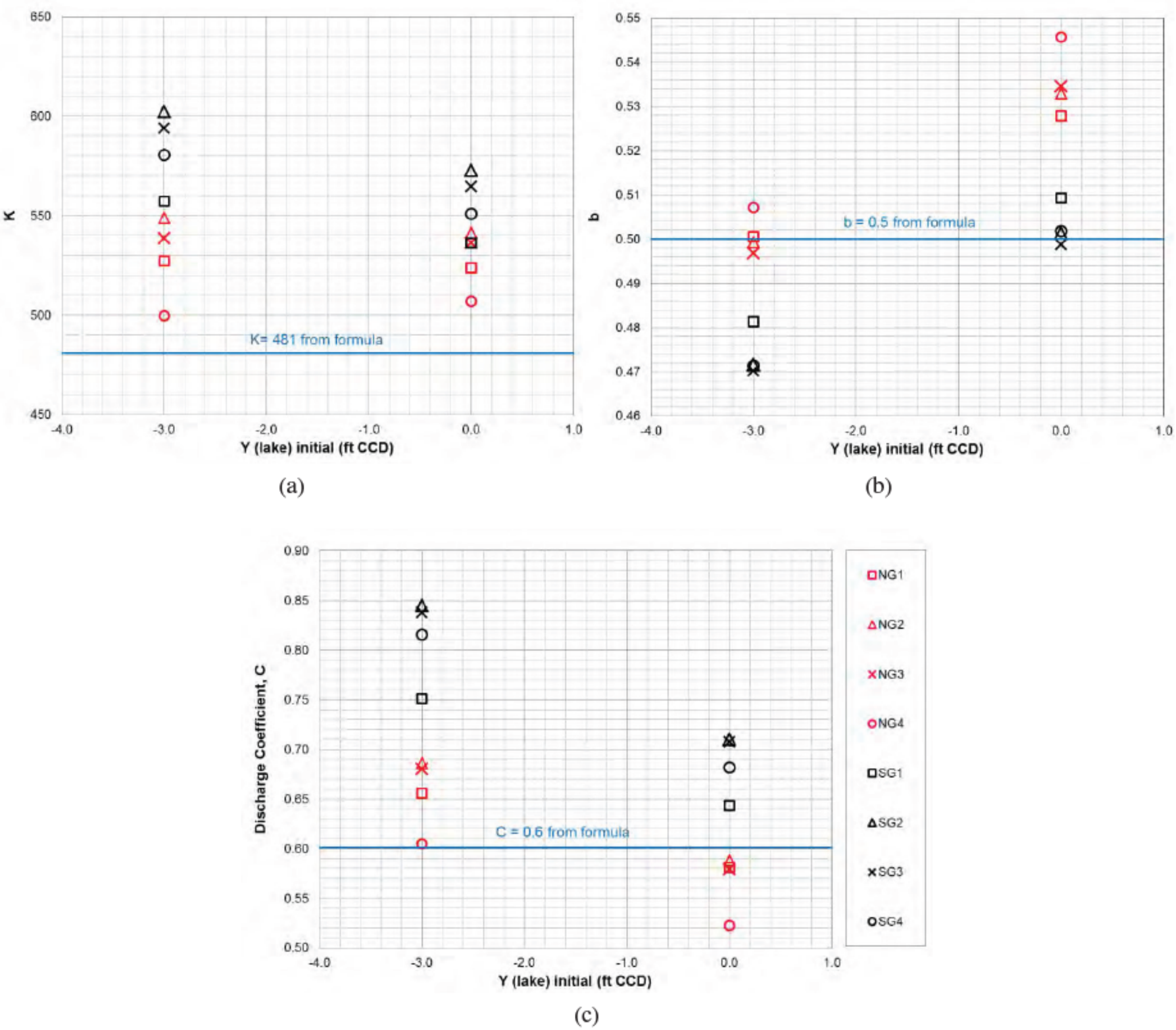
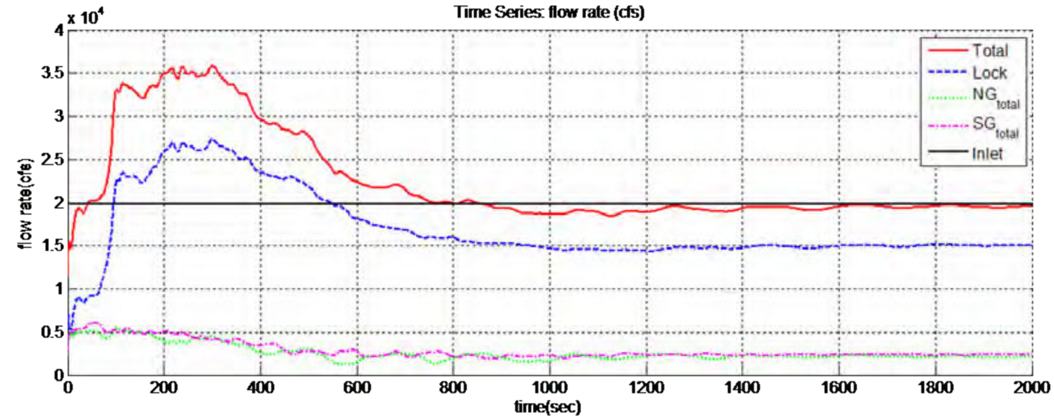
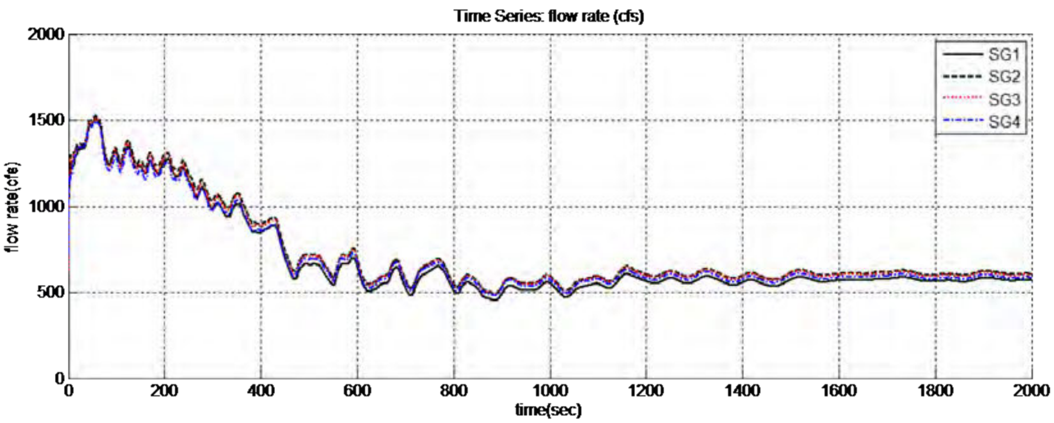


Figure 4.7: Relationships of fitted (a) K, (b) b, and (c) discharge coefficient C with initial water level in the Lake Michigan



(a)



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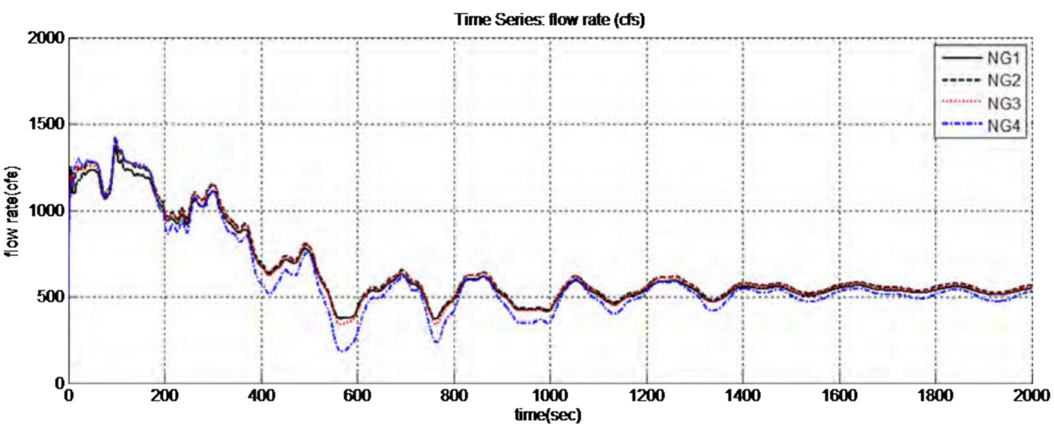
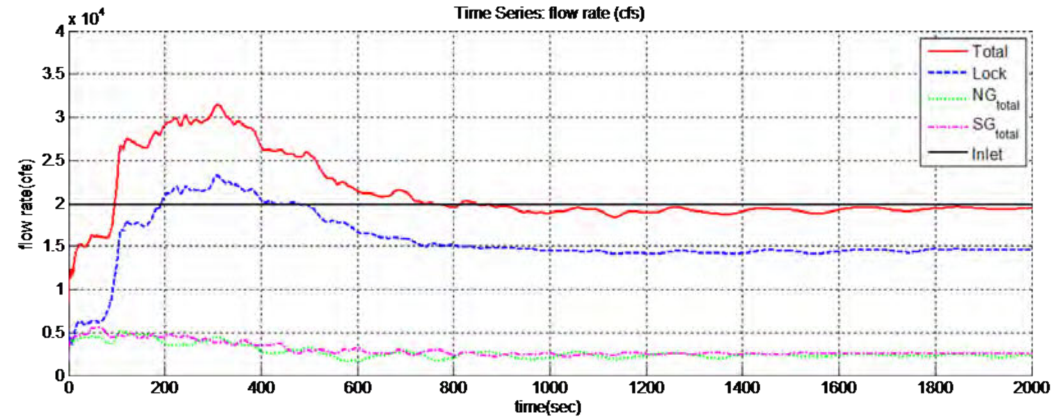
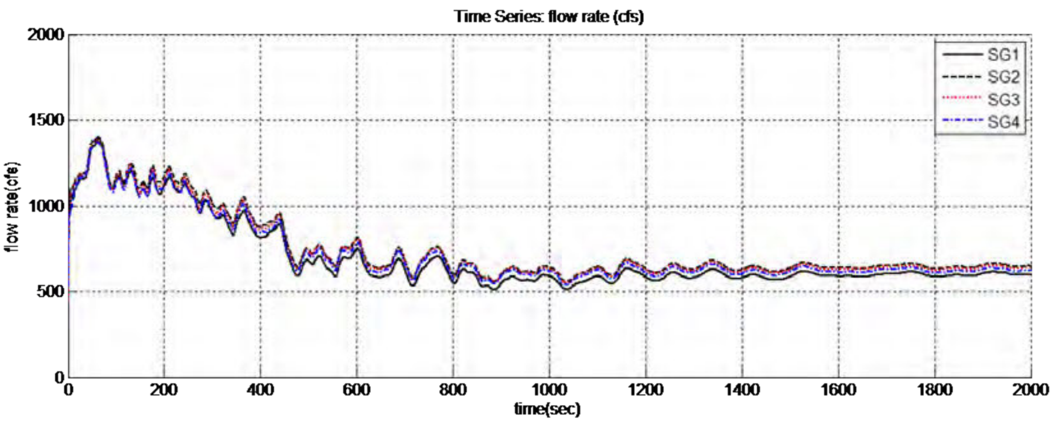


(c)

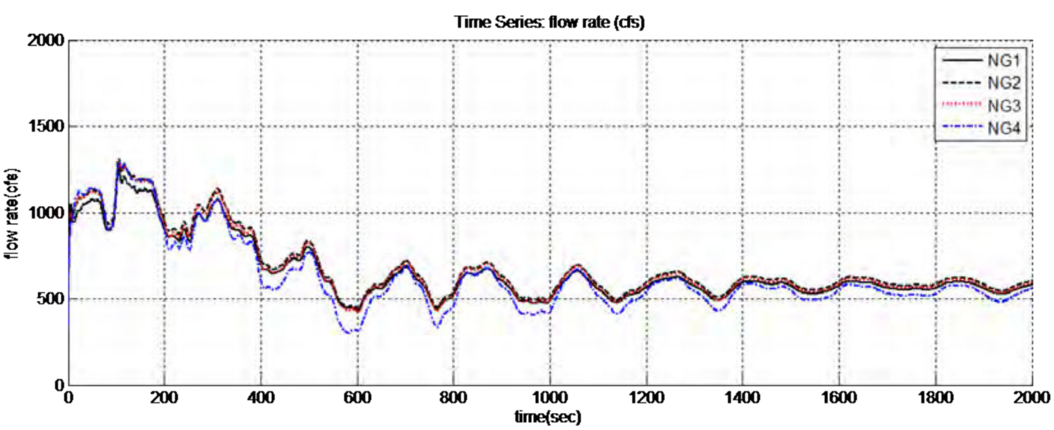
Figure 4.8: Timeseries of flow discharge through structures (C6-4 case with $Y_{i,lake}$ = 0 ft CCD and inflow = 20,000 cfs)



(a)



(b)



(c)

Figure 4.9: Timeseries of flow discharge through structures (C6-5 case with $Y_{i,lake}$ = -3 ft CCD and inflow = 20,000 cfs))

5 Bar Screen Effect at Sluice Gates

The possible presence of the invasive Asian Carp in the Chicago Area Waterways has prompted the investigation of several alternatives to hinder its migration into Lake Michigan and the other Great Lakes. One alternative under investigation is the installation of bar screens across the sluice gates at CRCW to prevent the fish from entering the Lake during a back-flow event. The research objectives for this section are:

1. determine how a screen affects the flow field around/through sluice gates
2. determine how a screen affects the discharge rating curve at CRCW due to the additional head loss.

The numerical simulations to determine the flow field around and through sluice gates with or without the vertical bar screen are performed by using a three-dimensional numerical model SSIIM (Section 5.1, Part I). Large differences in scale between the sluice gates and the physical dimension of the bar screen has prompted the use of an effective porosity parameter rather than directly modeling the individual bars of the bar screen. The bar screen has the clear spacing of 0.4 inches between bars and the width of an individual bar is 0.375 inches. For a gross gate opening of 100 sq ft, the net gate opening with the bar screen is 51.6 sq ft. Therefore, the effective porosity of the bar screen is:

$$n(\text{porosity}) = \frac{\text{volume of fluid}}{\text{total volume}} = 0.516 \tag{5.1}$$

In addition to the vertical bar screen design installed in the sluice gate stop-log grooves, an alternative design has the bar screen inclined 60-degree from horizontal on the river-ward side of the sluice gates. This alternative was also simulated. The modeling results for the alternate screen design were compared to vertical bar screen design and the case of no screen. Fluent was employed to model the alternative, inclined design (Section 5.3, Part II). The presence of the bar screen has the effect of modifying the discharge coefficient for the sluice gates. The rating curves are reassessed with the modified discharge coefficient.

5.1 Simulation Setup and Boundary Conditions (Part I)

For the first set of simulations, SSIIM is employed and the numerical domain is described in Figure 5.1. While only a single sluice gate is modeled, the use of a zero gradient boundary condition on side walls can be used to represent a group of sluice gates due to model symmetry. Constant inflow discharges (500 and 1,000 cfs) and downstream water levels (0 ft CCD) are applied. Since SSIIM is not able to model the free-surface, a head loss is calculated after the simulations by using the relative pressure and pressure difference. Therefore, the water level for the entire domain is assumed to be 0 ft CCD. A constant bed elevation of -25

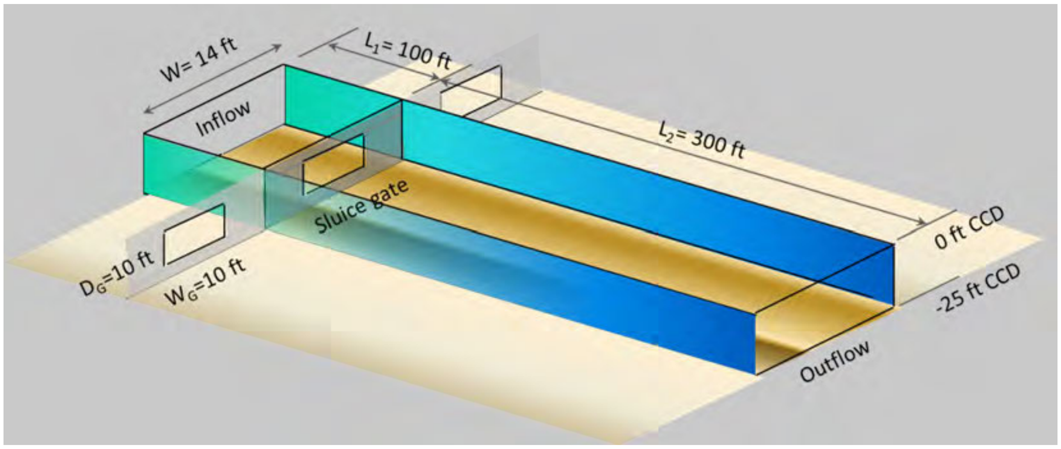


Figure 5.1: Numerical domain of a sluice gate with simplification

ft CCD is also assumed. For the case with a vertical screen, the porosity is assigned for the upstream portion of the sluice gate.

5.2 Simulation Results (Part I)

Four cases are simulated and they are identified as NS_500cfs, NS_1000cfs, SC_500cfs, and SC_1000cfs with NS indicating that no screen was present and the SC indicating the screened (vertical) case. Results are shown in Figures 5.2–5.5. When the results are normalized, the results are independent of discharge, therefore only the results for the 1000 cfs case are shown. Velocity, turbulent kinetic energy, and pressure distributions in the XZ-plane (longitudinal plots) near the sluice gate and the center of channel are shown in Figures 5.2 and 5.3 for the case without a screen and with screen, respectively. The results in the YZ-plane (cross sectional plots) are presented in Figures 5.4 and 5.5. The results indicate that the effect of the vertical screens is the reduction of turbulence and the elimination of large-scale flow patterns or pressure non-uniformities. Figure 5.6 shows the quantitative result of the depth averaged velocity profile near the sluice gates for all four cases. The results show the effect of the screen on velocities near and in front of the sluice gate, which is also shown in the cross-sectional plots in Figures 5.4 and 5.5.

The head loss through a sluice gate is computed by using the pressure difference in the field and the results are plotted in Figure 5.7. The head loss is also calculated by considering the flow and the effective areas of screen openings, the latter being the sum of the vertical projections of the openings. The head loss through a clean bar screen is calculated from the following formula:

$$h = 0.0729(V^2 - v^2) \tag{5.2}$$

where h = head loss in m, V = velocity through the screen in m/s, v = velocity before the screen in m/s.

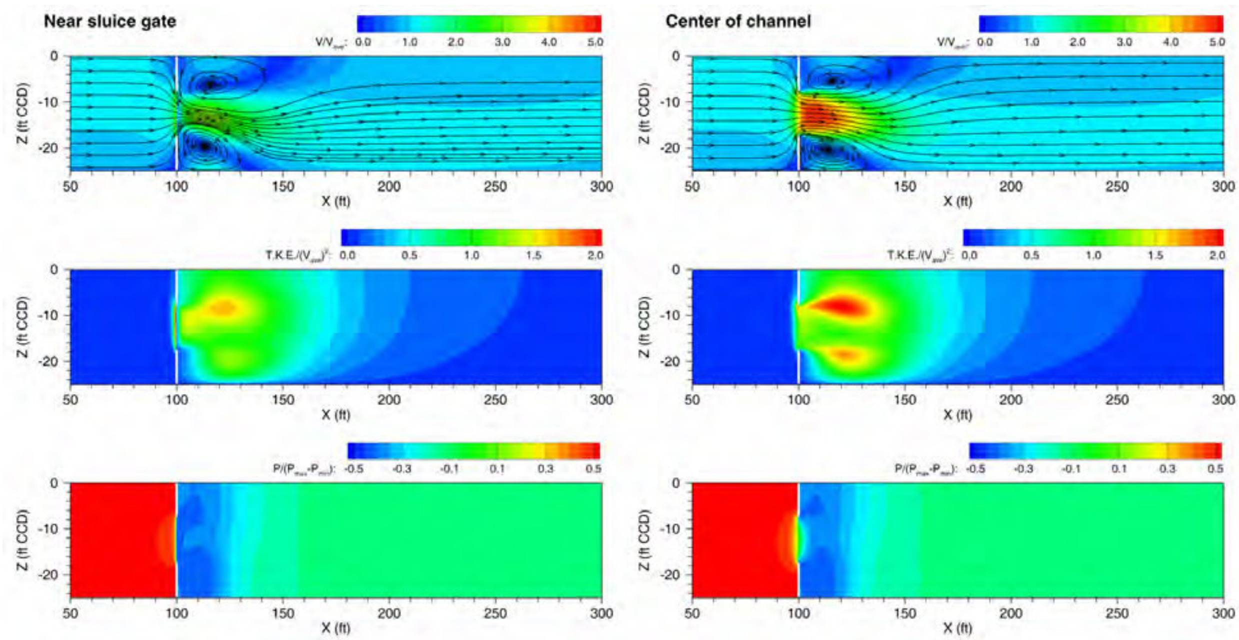


Figure 5.2: Velocity (upper), turbulent kinetic energy (middle) and pressure (lower) distributions in XZ-plane at near sluice gate (left) and center of channel (right), Q=1,000 cfs without a screen

Another formula that can be used to determine the head loss through a bar screen rack is Kirschmer's equation:

$$h = \beta \frac{W}{b}\frac{4}{3} h_v \sin q \tag{5.3}$$

where β= bar shape factor (2.42 for sharp edge rectangular bar, 1.83 for rectangular bar with semicircle upstream, 1.79 for circular bar and 1.67 for rectangular bar), W=maximum width of bar in m, b=minimum clear spacing between bars in m, h_v=velocity head of flow approaching rack in m/s, and q= angle of inclination of rack with respect to the horizontal (q=90 for the vertical bar screen). The head loss through fine screen is given by

$$h = \frac{1}{2g}\frac{Q}{CA}^{2} \tag{5.4}$$

where Q=discharge in ft^3/s, C=coefficient of discharge (typical value 0.6), A=effective submerged open area in ft^2.

By using the head loss determined from the previously discussed four cases, (two with screen and two without) at two discharges (500 and 1000 cfs), the following correction factors have been determined to adjust the sluice gate discharge coefficients to account for the presence of the screens.

- Q_1 = Ideal discharge
- Q_2 = monitored discharge without screen effect (which is the discharge obtained from the original

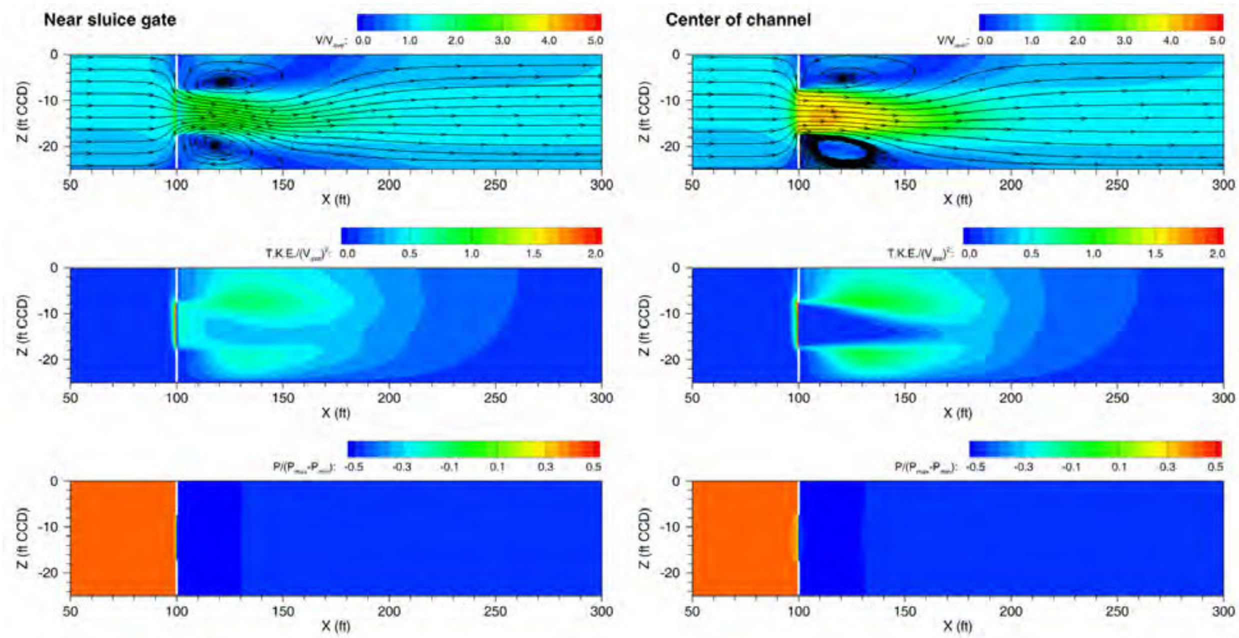


Figure 5.3: Velocity (upper), turbulent kinetic energy (middle) and pressure (lower) distributions in XZ-plane at near sluice gate (left) and center of channel (right), Q=1,000 cfs with a vertical screen

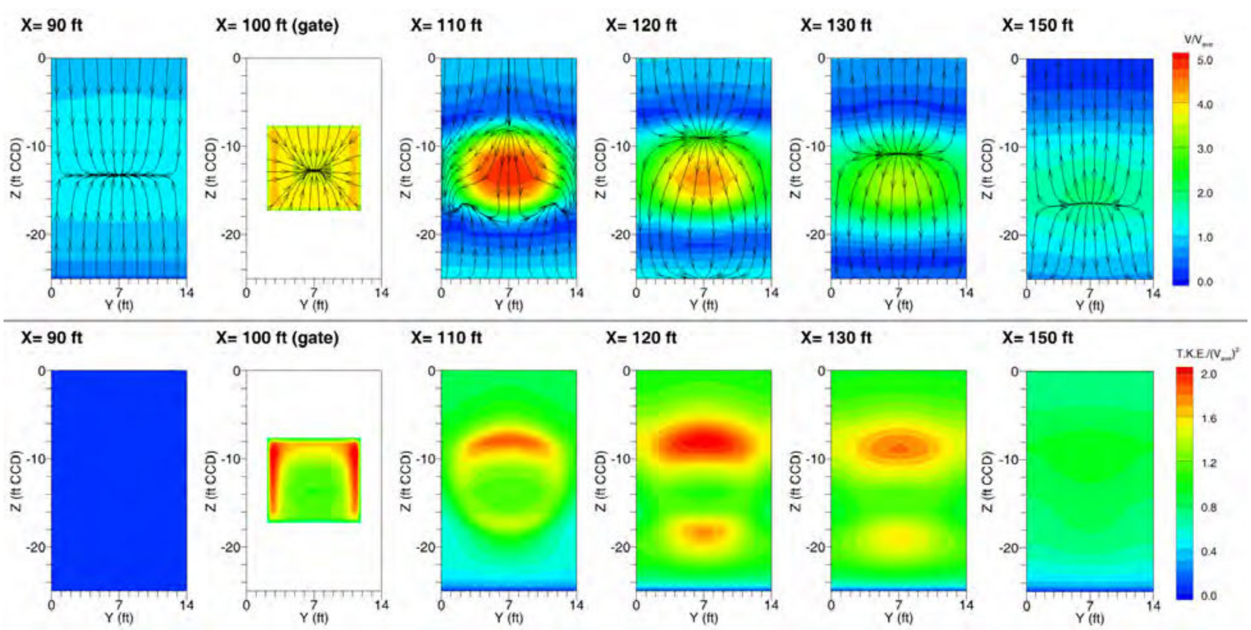


Figure 5.4: Velocity (upper) and turbulent kinetic energy (lower) distributions in cross-sections, Q=1,000 cfs without a vertical screen

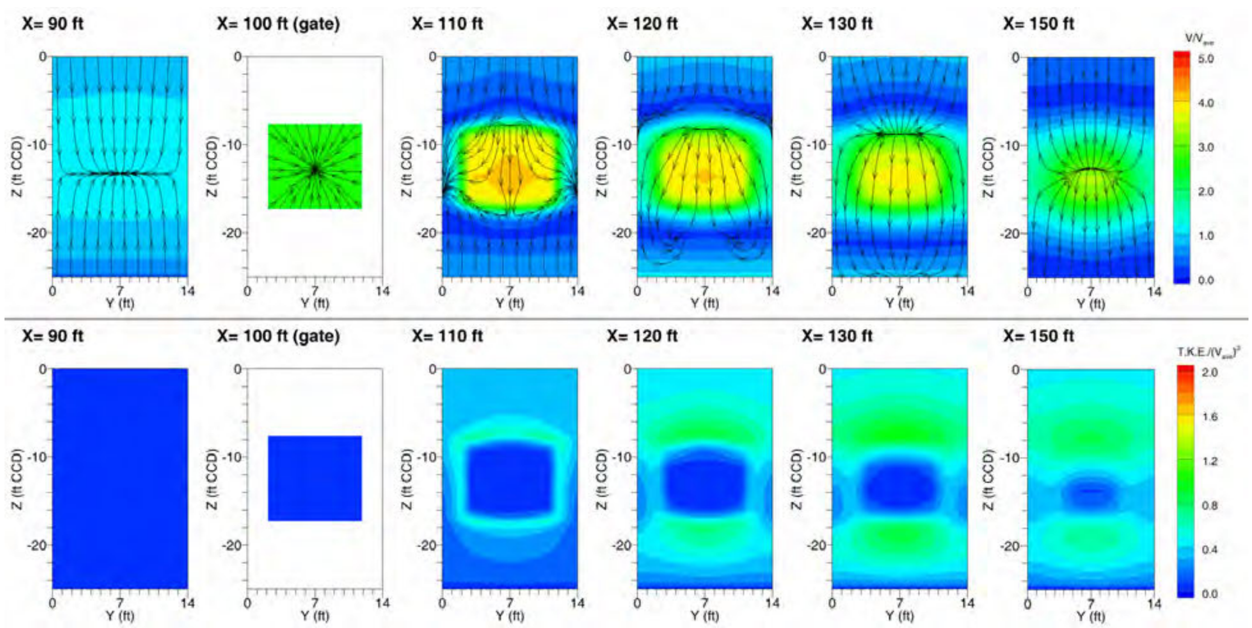


Figure 5.5: Velocity (upper) and turbulent kinetic energy (lower) distributions in cross-sections, Q=1,000 cfs with a vertical screen

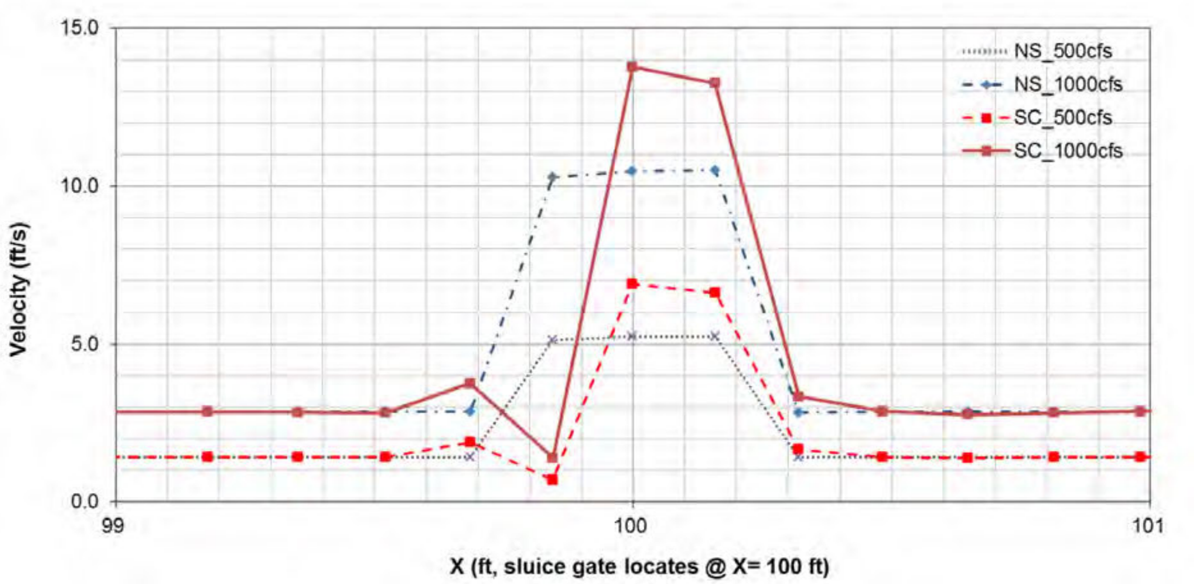


Figure 5.6: Depth averaged velocity profiles near screen

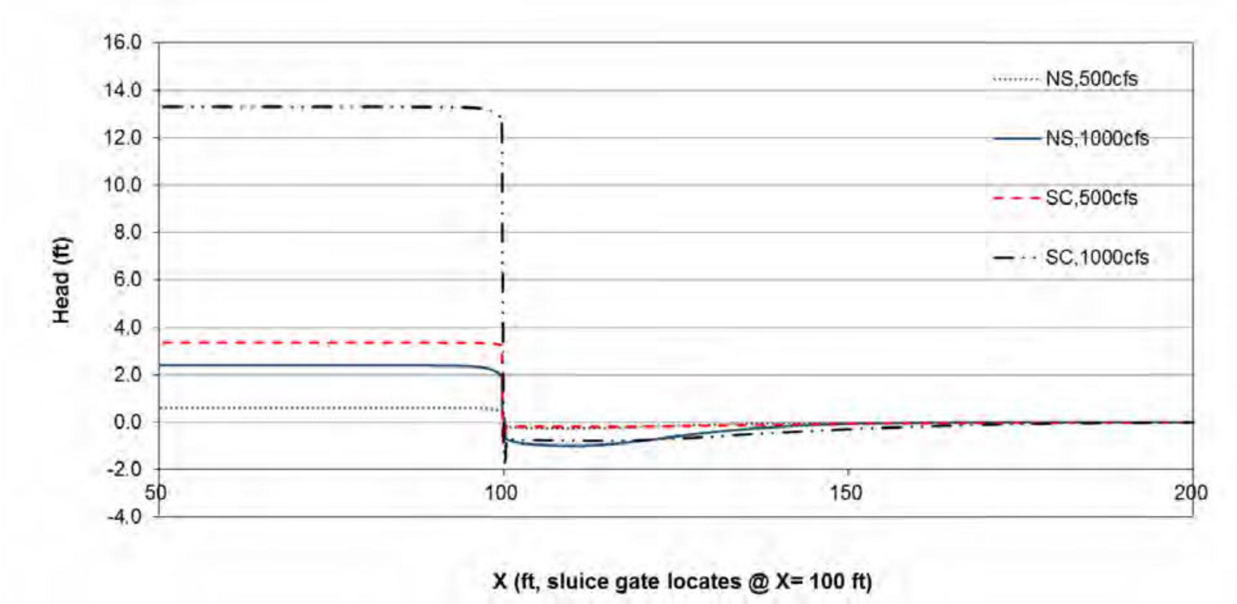


Figure 5.7: Headloss through a sluice gate

rating curves)

- Q_3 = corrected discharge with screen effect
- C_2= discharge coefficient without screen effect
- C_3= discharge coefficient with screen effect
- C_0= correction factor to modify Q_2 with Q_3 in the rating curve

$$Q_2 = C_2 Q_1 \tag{5.5}$$

$$Q_2 = C_3 Q_1 \tag{5.6}$$

Therefore,

$$Q_3 = \frac{C_3}{C_2} Q_2 = C_0 Q_2 \tag{5.7}$$

The corrected discharge coefficient C_0 is 0.42 (=$0.34/0.806$) which means that the discharge through the gate will be reduced by 42% due to the presence of the bar screen. This value compares well with C_0 = 0.46 from Kirchner formula. However, the reduction in discharge of nearly 50% for the sluice gates due to the screen is not desirable and could significantly impact flood control effort during extreme storm events. Therefore, an alternate screen design is investigated in the next section.

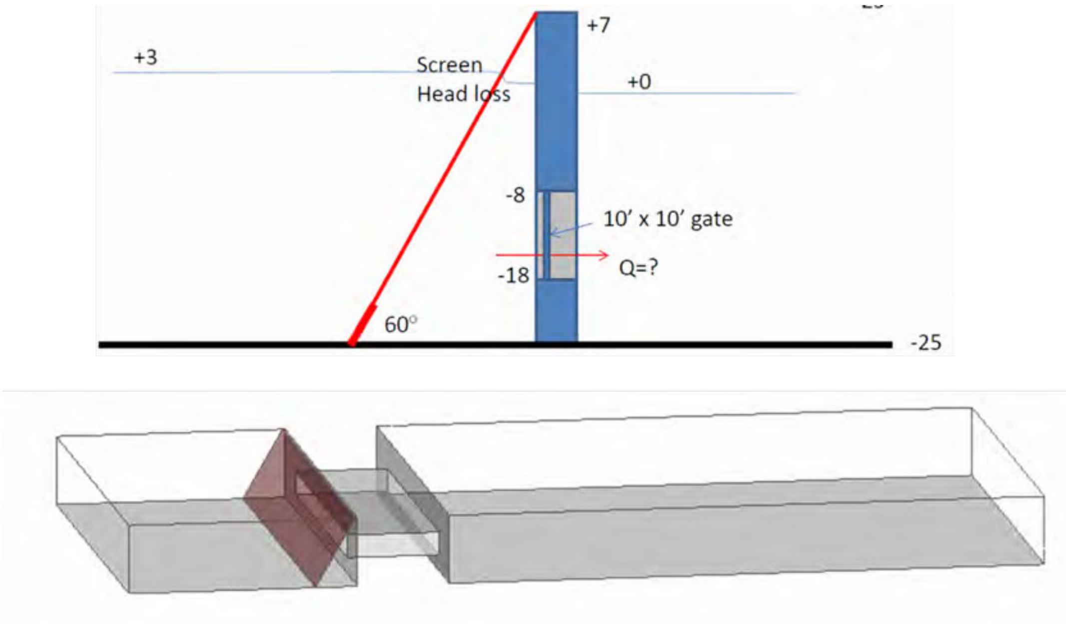


Figure 5.8: Design of the inclined screen and the dimensions of the hydraulic structure (upper) and numerical domain

5.3 Simulation Setup and Boundary Conditions (Part II)

The second set of the simulations was performed with a detailed representation of the hydraulic structure geometry without simplification. The design of the 60-degree inclined screen and the dimensions of the hydraulic structure and numerical domain are depicted in Figure 5.8.

In Fluent, the source term (Si) in the momentum equation to simulate the porous media consists of two terms.

$$S_i = -\left(\sum_{j=1}^{3} D_{ij}\mu v_j + \sum_{j=1}^{3} C_{ij}\frac{1}{2}\rho|v|v_j \right) \tag{5.8}$$

The first term is a viscous loss term (Darcy) and the second term is an inertial loss term. For a simple homogeneous porous media, equation (5.8) is

$$S_i = -\left(\frac{\mu}{a}v_i + C_2\frac{1}{2}\rho|v|v_j \right) \tag{5.9}$$

where a is the permeability and C_2 is the inertial resistance factor (or a loss coefficient per unit length along the flow direction). Herein, the 1-D simplification for a thin membrane is applicable since a and C_2 are determined by using the first set of simulations (Part I).

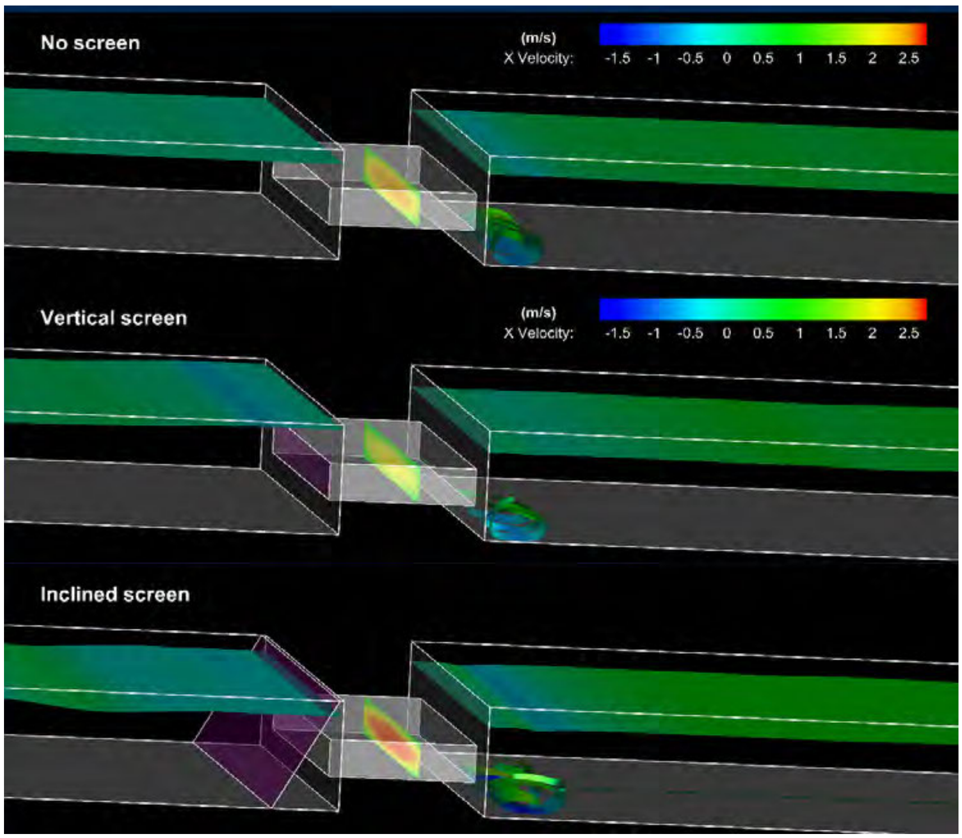


Figure 5.9: Velocity distributions with free surface and streamlines for the three cases of no screen (upper), vertical screen (middle), and inclined screen (lower). The screen is colored with purple.

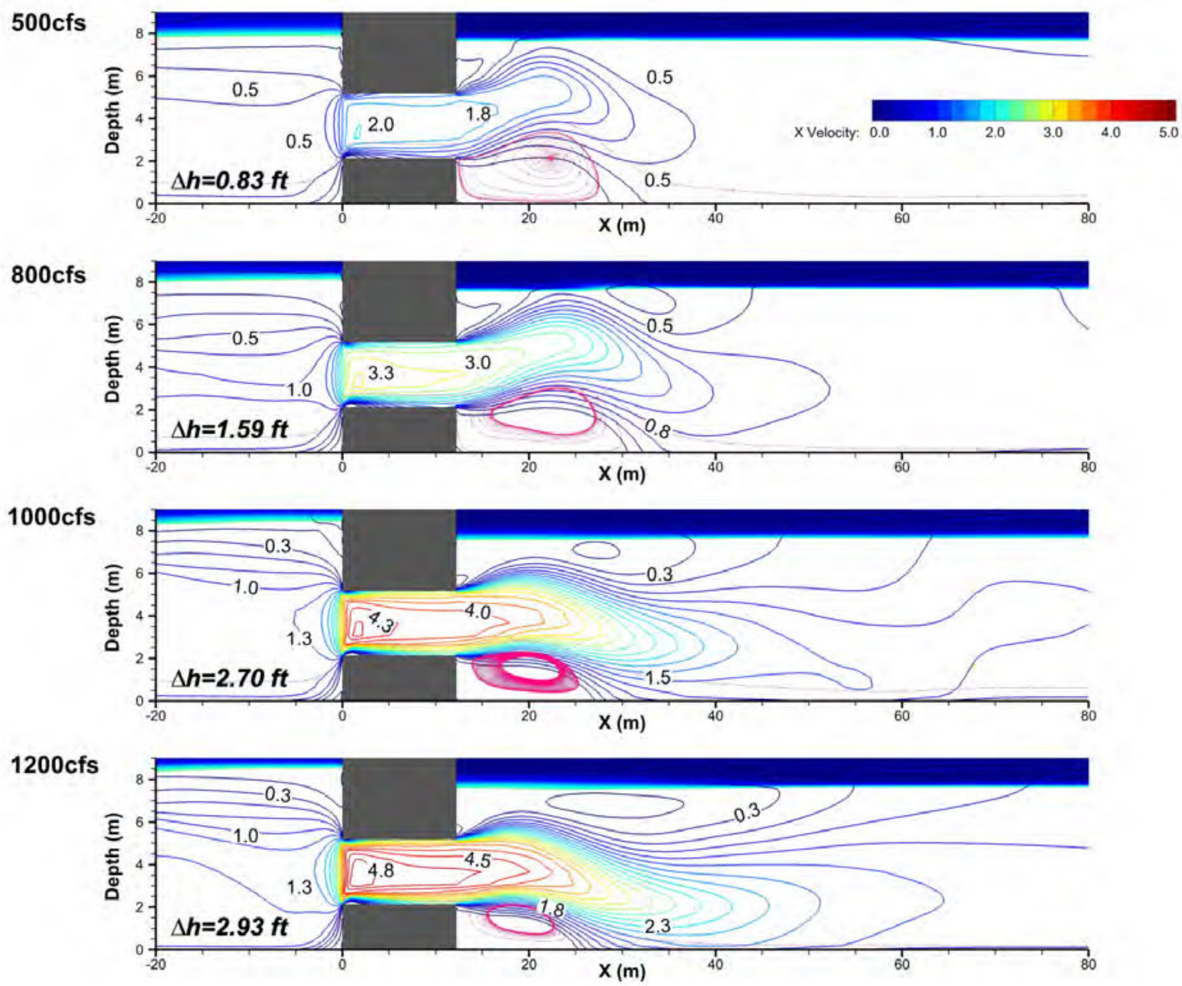


Figure 5.10: , Free surface and velocity distributions in corresponding flow discharge (500, 800, 1000, and 1200 cfs) and headloss at the sluice gate without a bar screen

5.4 Simulation Results (Part II)

The relationship between flow discharge and head loss is investigated with four different discharge (500, 800, 1000, and 1200 cfs) at the sluice gate without a bar screen (Figure 5.10). In the figures, the sluice structures are colored grey and start at x= 0 m, and flow velocity is indicated with colored contours within a white background while the region of air is within the blue background. The free surface elevations change after water passes the sluice gate structure. As the inflow increases, the head loss at the sluice gates also increase. Increasing head losses results in a higher free surface at the upstream end of the sluice-gate structure. The size of the re-circulation behind the structure reduces with increasing flow.

Three different cases are simulated at a constant discharge of 500 cfs; no screen, vertical screen and inclined screen (Figure 5.9). Three dimensional plots of the cases are shown in Figure 5.9 with the velocity distri-

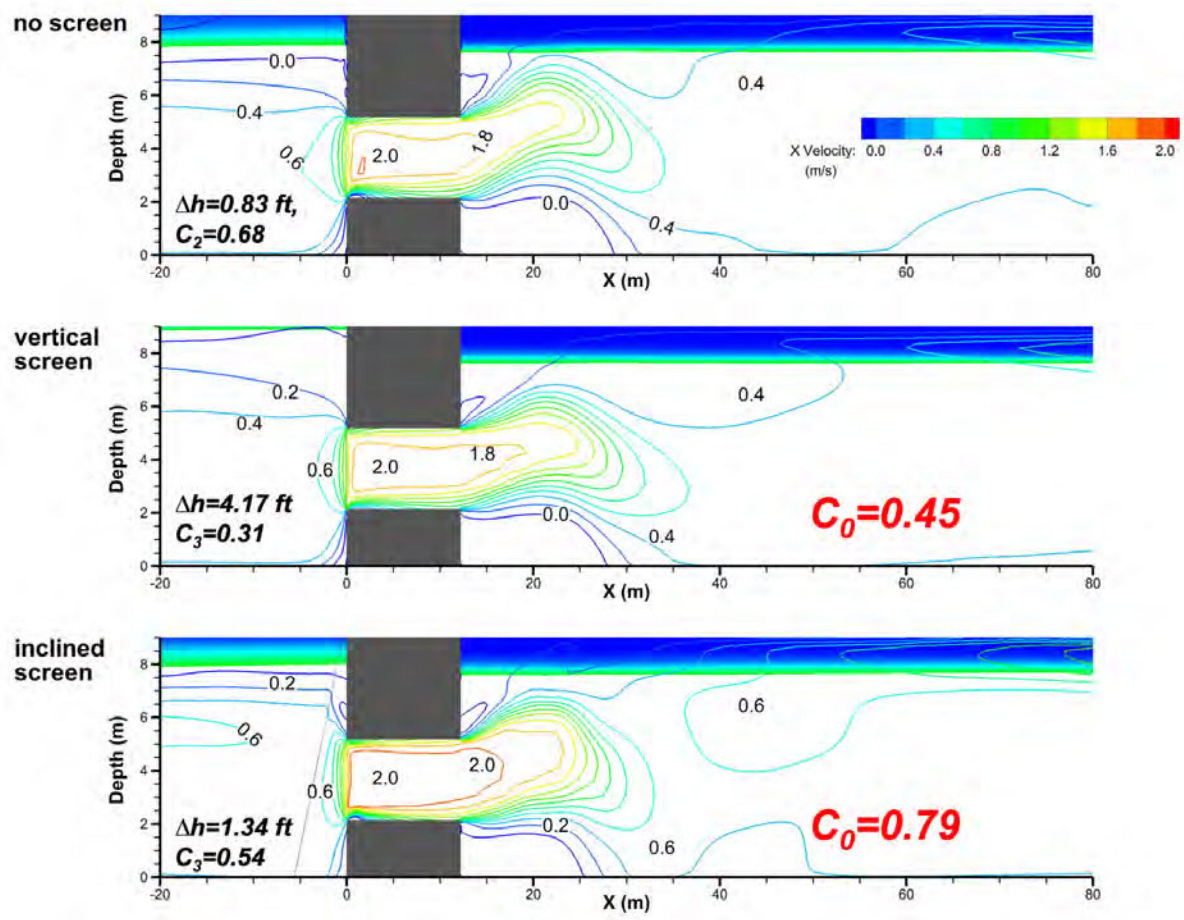


Figure 5.11: Free surface and velocity distributions and headloss at the sluice gate in corresponding cases of no screen (upper), vertical screen (middle), and inclined screen (lower) when Q=500 cfs

bution and free surfaces at both the river and lake sides. The velocity distribution in front of the sluice gate is effected by the screen. Both vertical and inclined screens change the velocity distribution in front of the sluice gate (Figure 5.11). However, the amount of head loss caused by the presence of the screen exhibits a large difference between the two screen designs. The highest head loss occurs for the case of vertical screen as shown in Figure 5.11.

By using the case of no screen as a reference, the correction factor in equation (5.7) is calculated for both vertical and inclined screen cases. The correction factor for the vertical screen is 0.45 which is almost the same as the value (0.42) calculated in Part I, while from the value for the inclined screen is 0.79. The new rating curves are provided in Figures 5.12 and 5.13 for the north gates and the south gates, respectively, with the correction factor of 0.79.

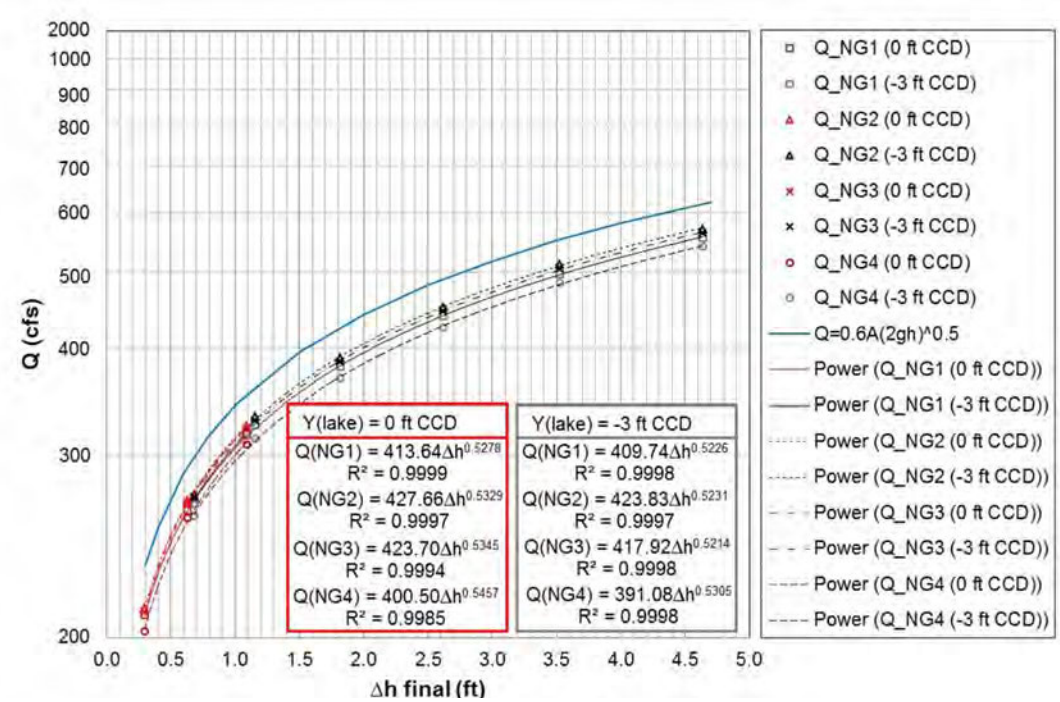


Figure 5.12: Modified rating curves for north gates with correction factor of 0.79

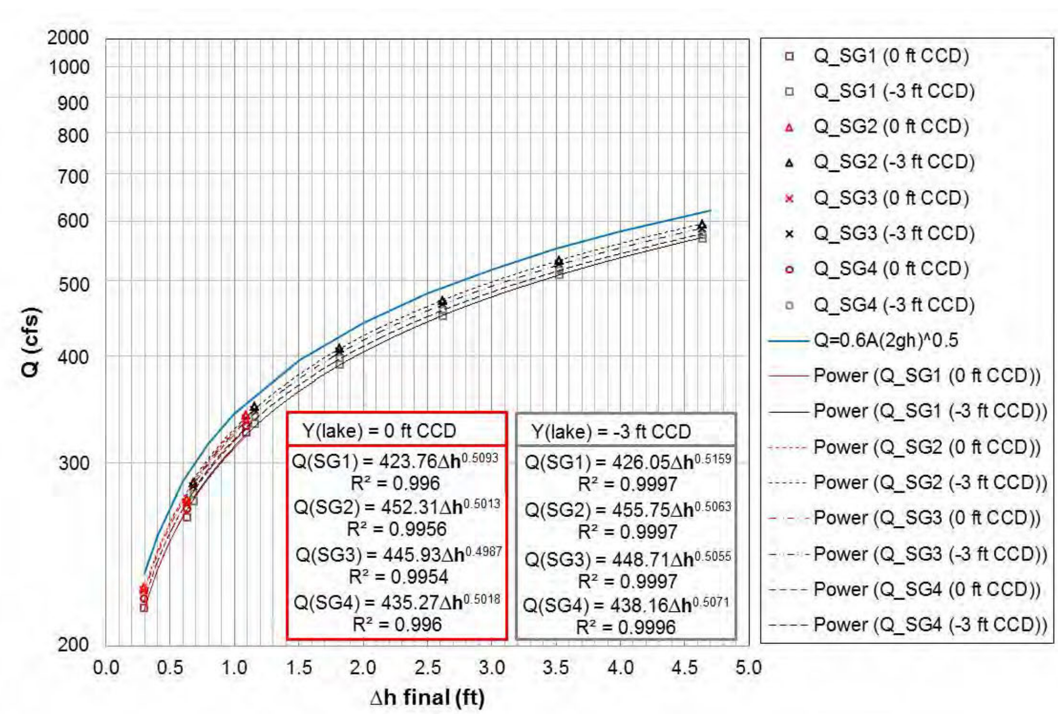


Figure 5.13: Modified rating curves for south gates with correction factor of 0.79

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A Velocity Distribution at Lock Chamber

A.1 Simulation Setup and Boundary Conditions

1. Boundary Conditions

   - Upstream: inflow at inlet
   - Downstream: outflow at outlet with constant water surface level (0 ft CCD) in Lake Michigan
   - Constant bed elevation of -24.94 ft CCD is assumed

2. Initial Conditions

   - Assume the water surface level in Chicago River is constant (3 ft CCD) before opening the lock and gates (north and south- gates)
   - Assume the initial velocity in whole domain is 0 ft/s

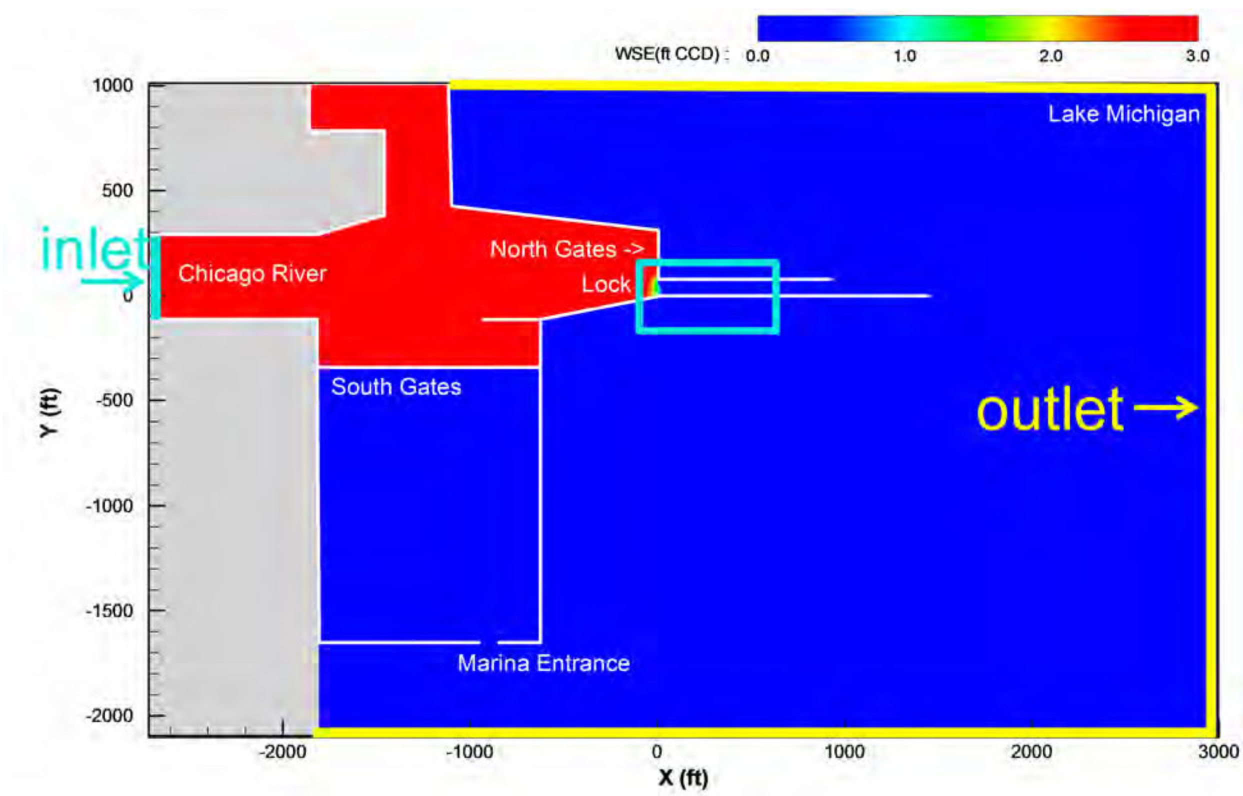


Figure A.1: Numerical domain and boundary conditions

A.2 Simulation Results

- Inflow is set constant within simulation time
- Flow discharge through each hydraulic structure is monitored at the normal plane of the structure
- Flow discharge changes in time until it converges at steady flow condition
- Case 1
- Total inflow= 15,000 cfs
- Monitored Q_{lock}=11,200 cfs (converged at steady flow)
- Case 2
- Total inflow= 33,000 cfs
- Monitored Q_{lock}=25,000 cfs (converged at steady flow)

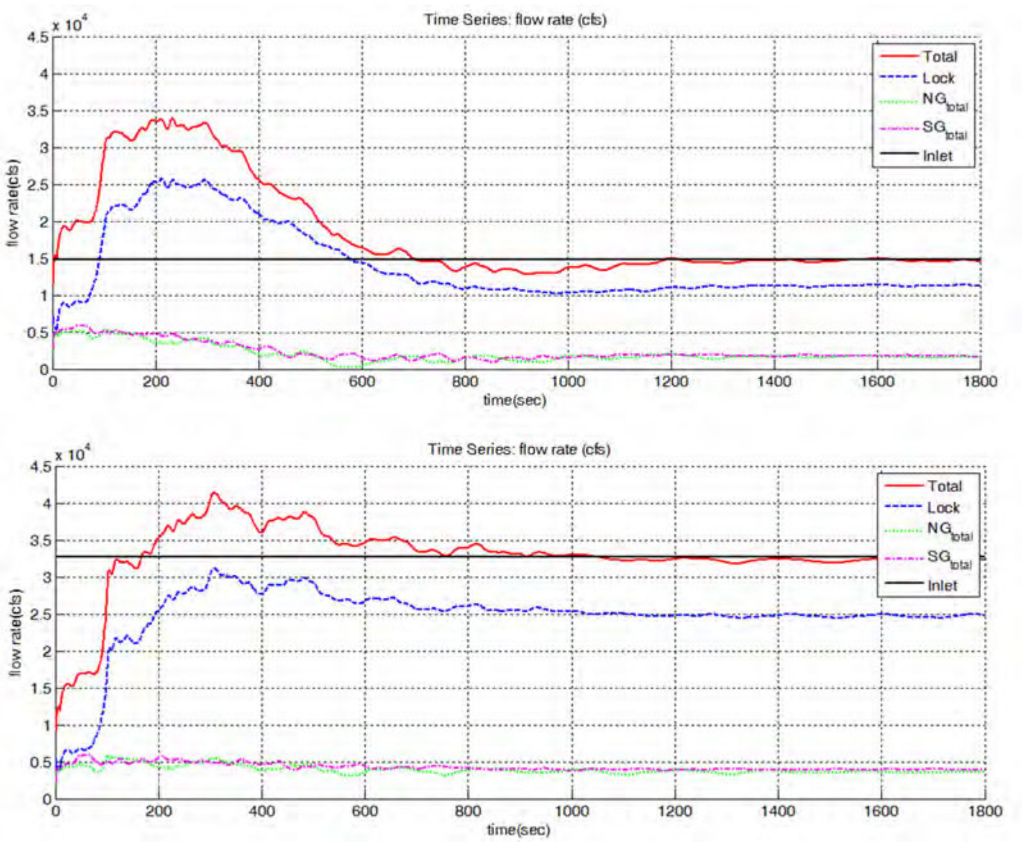


Figure A.2: Timeseries of flow rate (cfs) of Case 1 (upper) and Case 2 (lower)

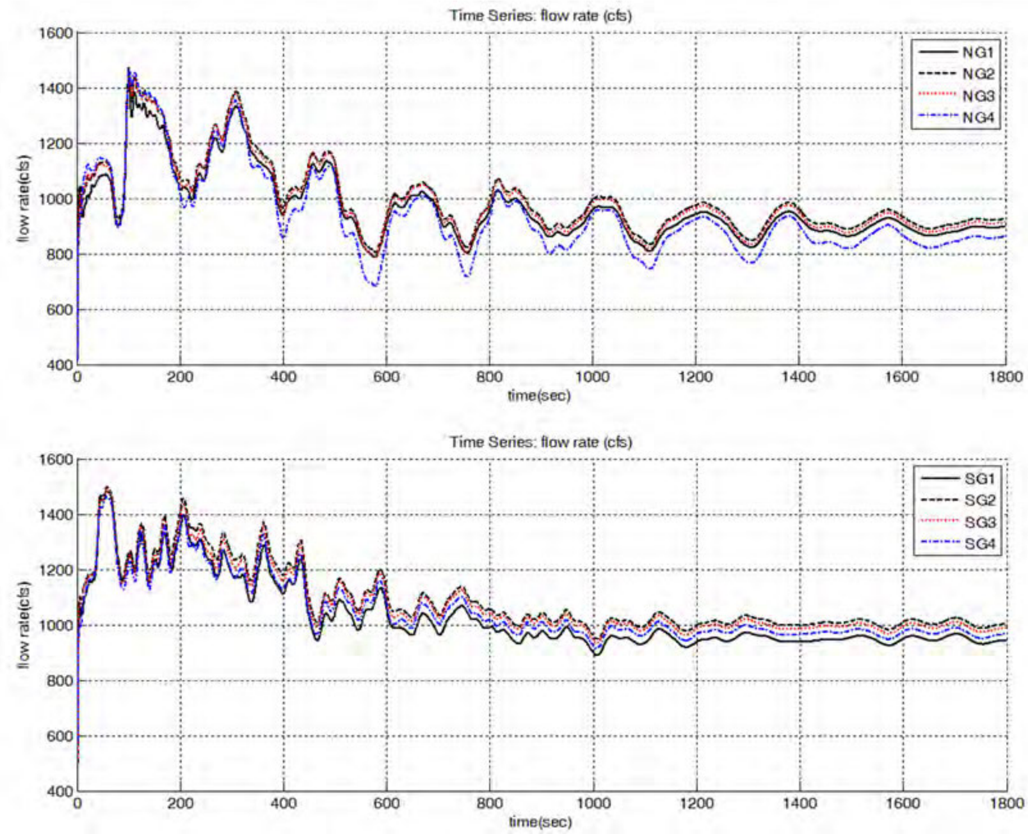


Figure A.3: Timeseries of flow rate (cfs) through each sluice gate of Case 2, North gates (upper) and south gates (lower)

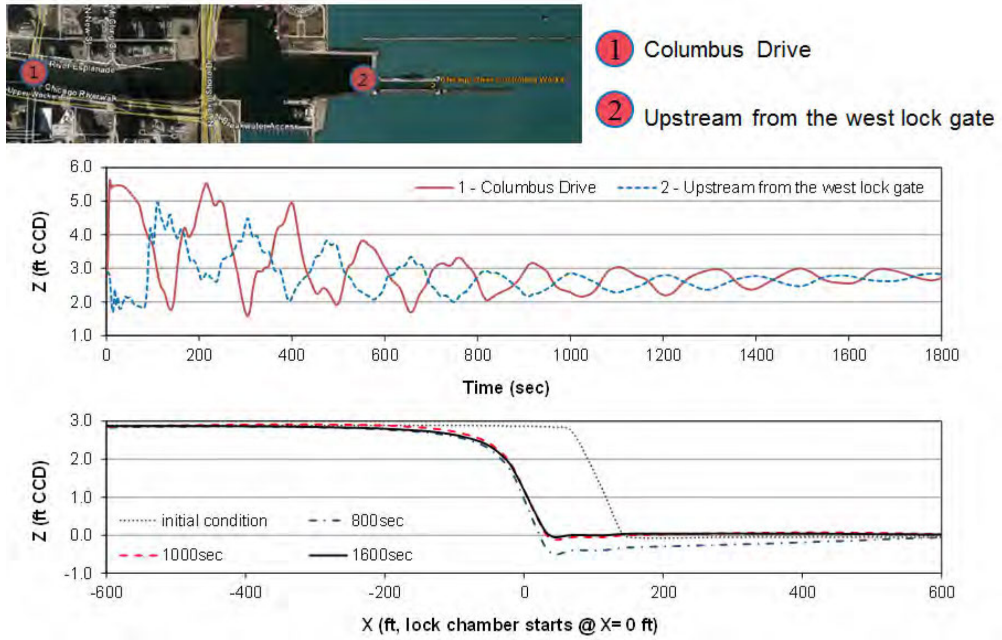


Figure A.4: Timeseries of water surface level (upper) and the water surface profile in X-direction at four different times (lower) (Case 2)

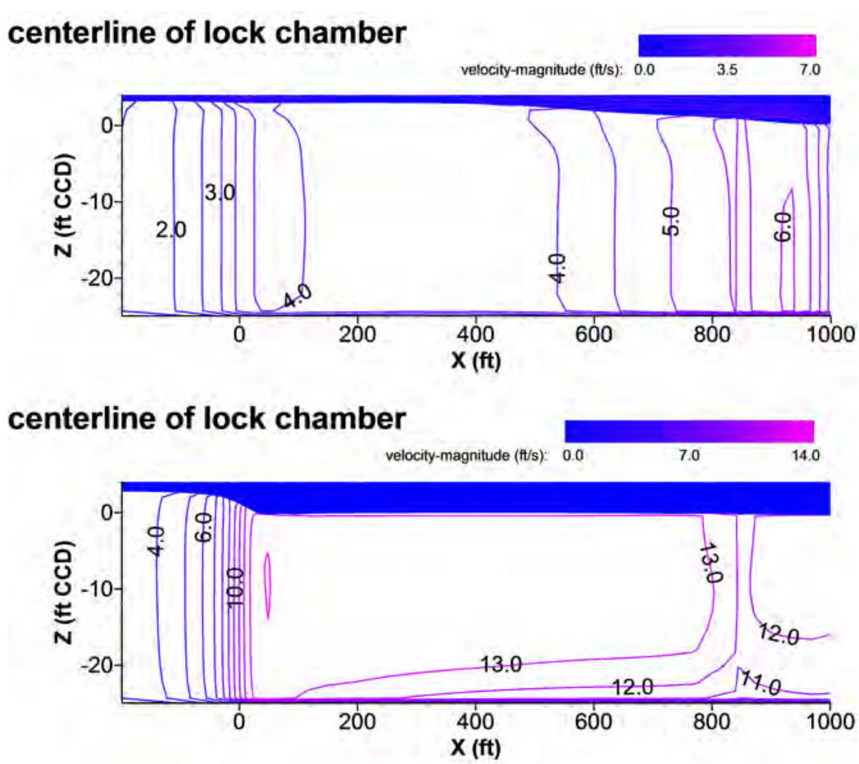


Figure A.5: Velocity distribution with surface profile of Case 1 (upper) and Case 2 (lower)

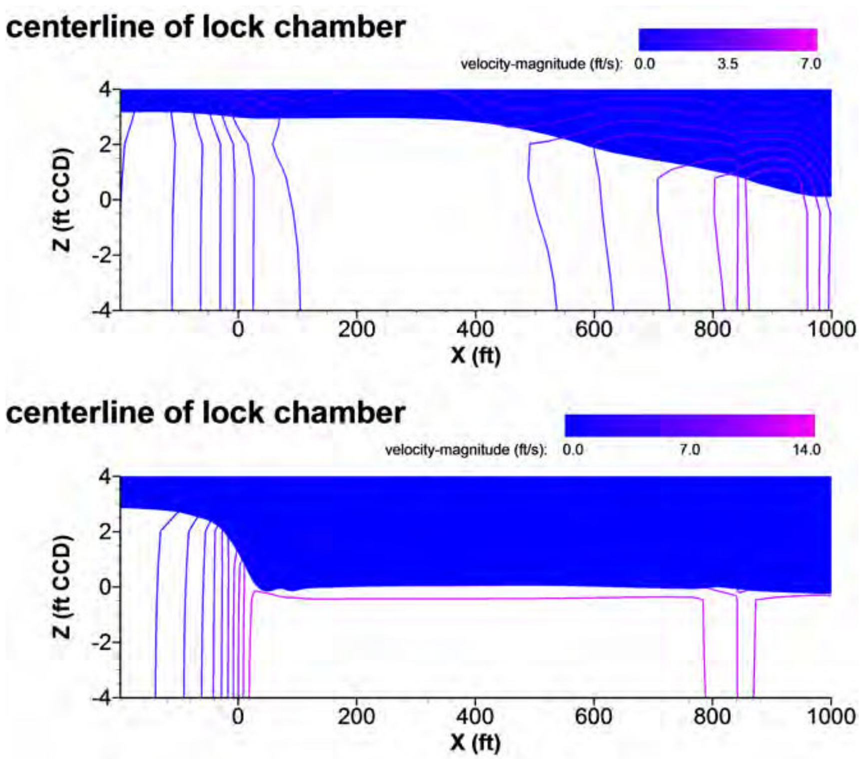


Figure A.6: Surface profile near lock (river-side) of Case 1 (upper) and Case 2 (lower)

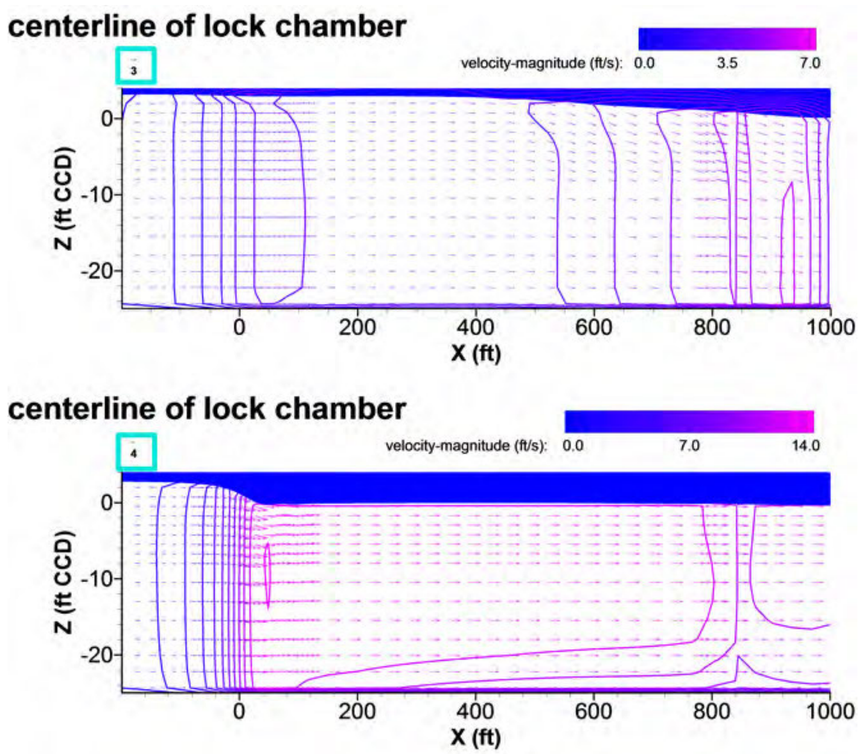


Figure A.7: Vector distribution (ft/s) of Case 1 (upper) and Case 2 (lower)

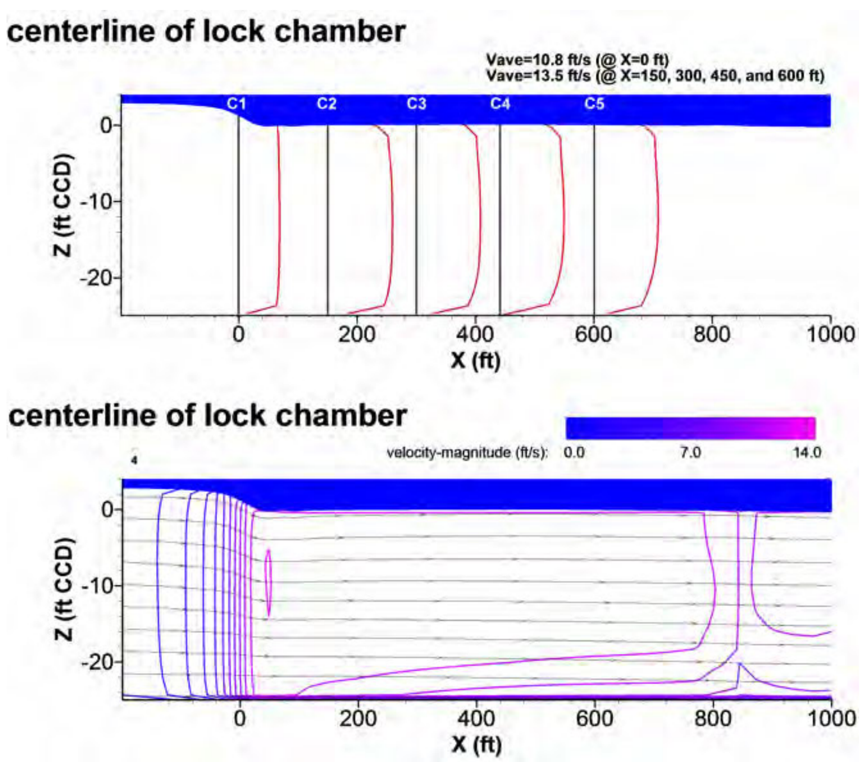
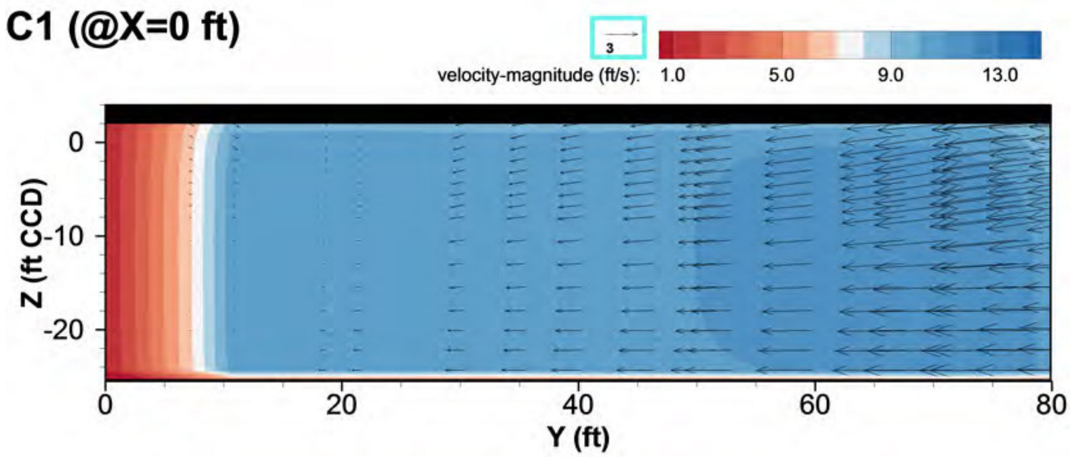


Figure A.8: Velocities (upper) and streamline (lower) of Case 2



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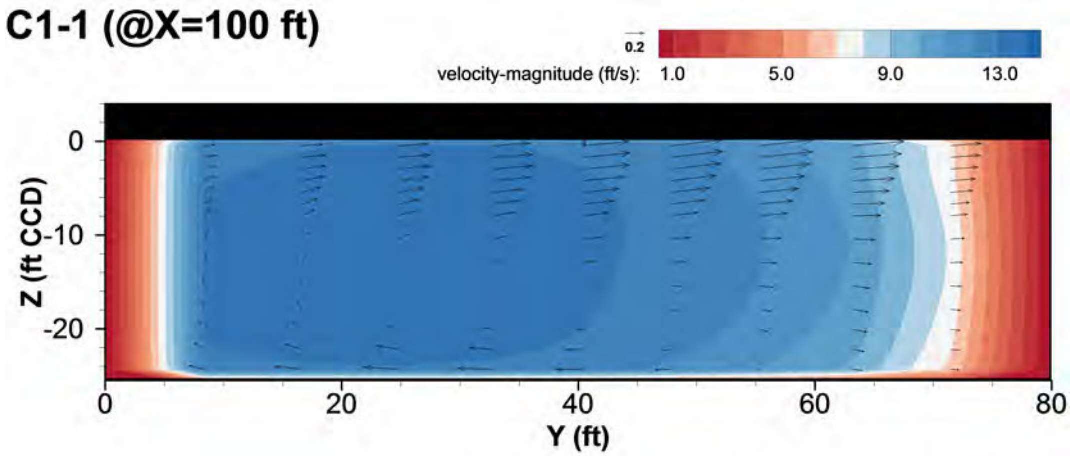

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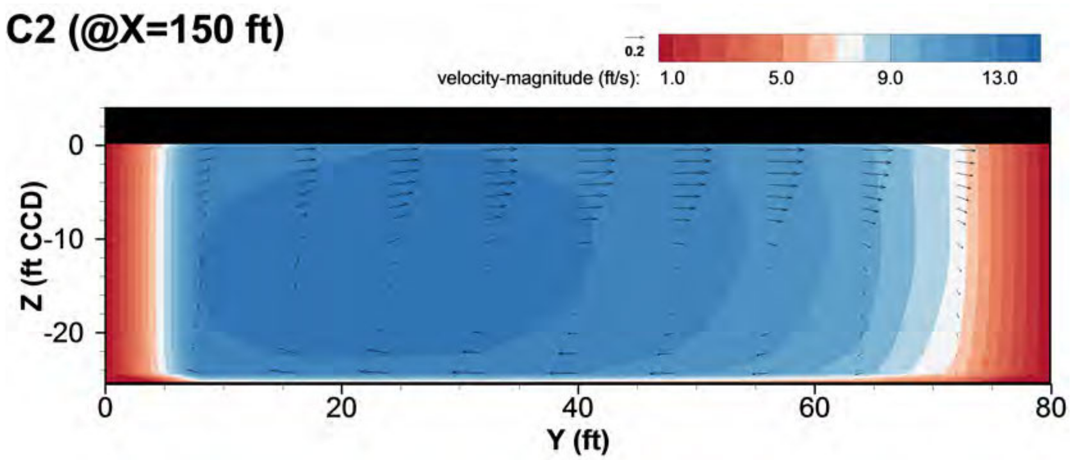

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Figure A.9: Velocity distribution with streamline at cross-sections at time = 1800 sec (Case 2 - Q_{lock} =25,000 cfs of steady flow)

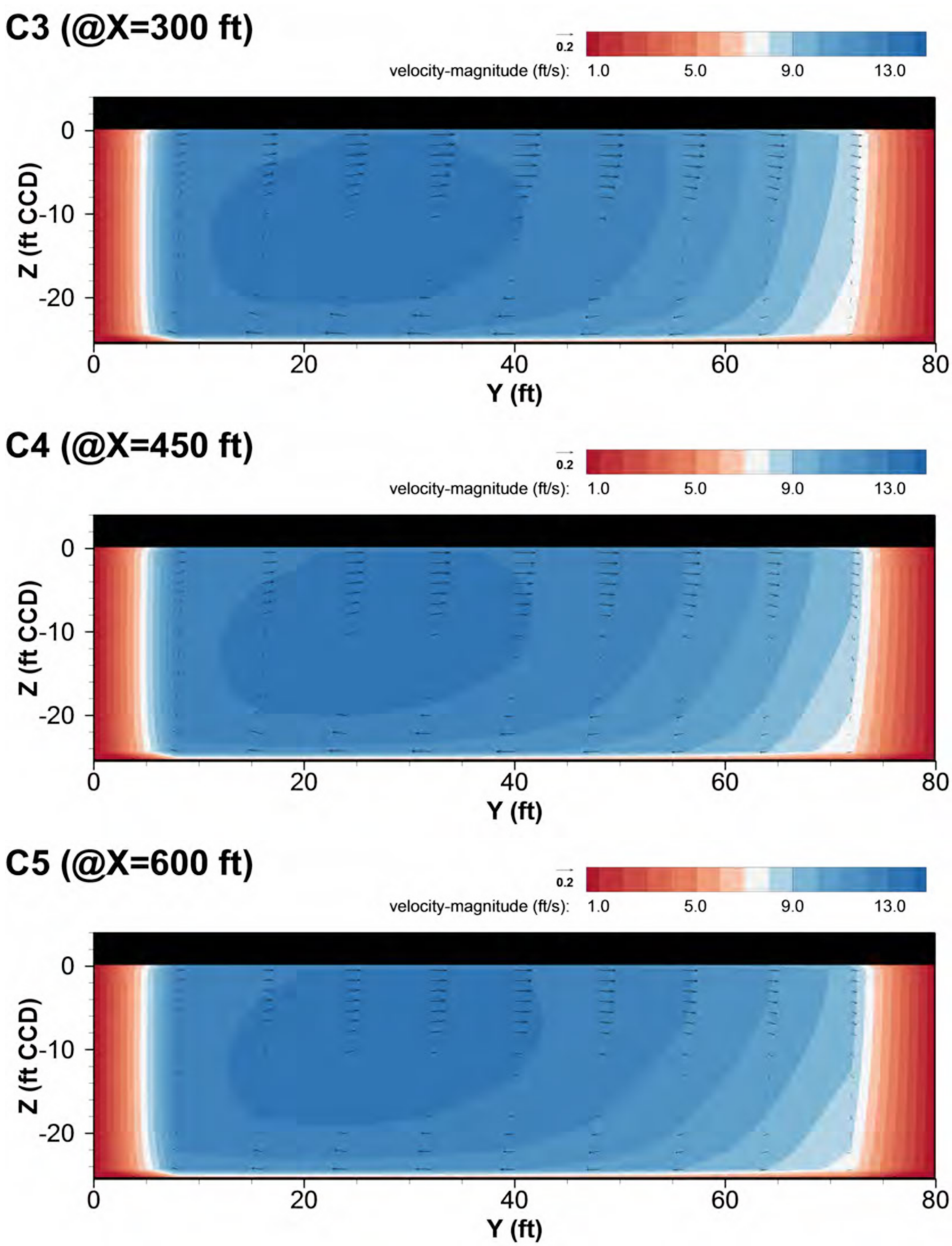


Figure A.10: Velocity distribution with streamline at cross-sections at time = 1800 sec (Case 2 - Q_{lock} =25,000 cfs of steady flow)

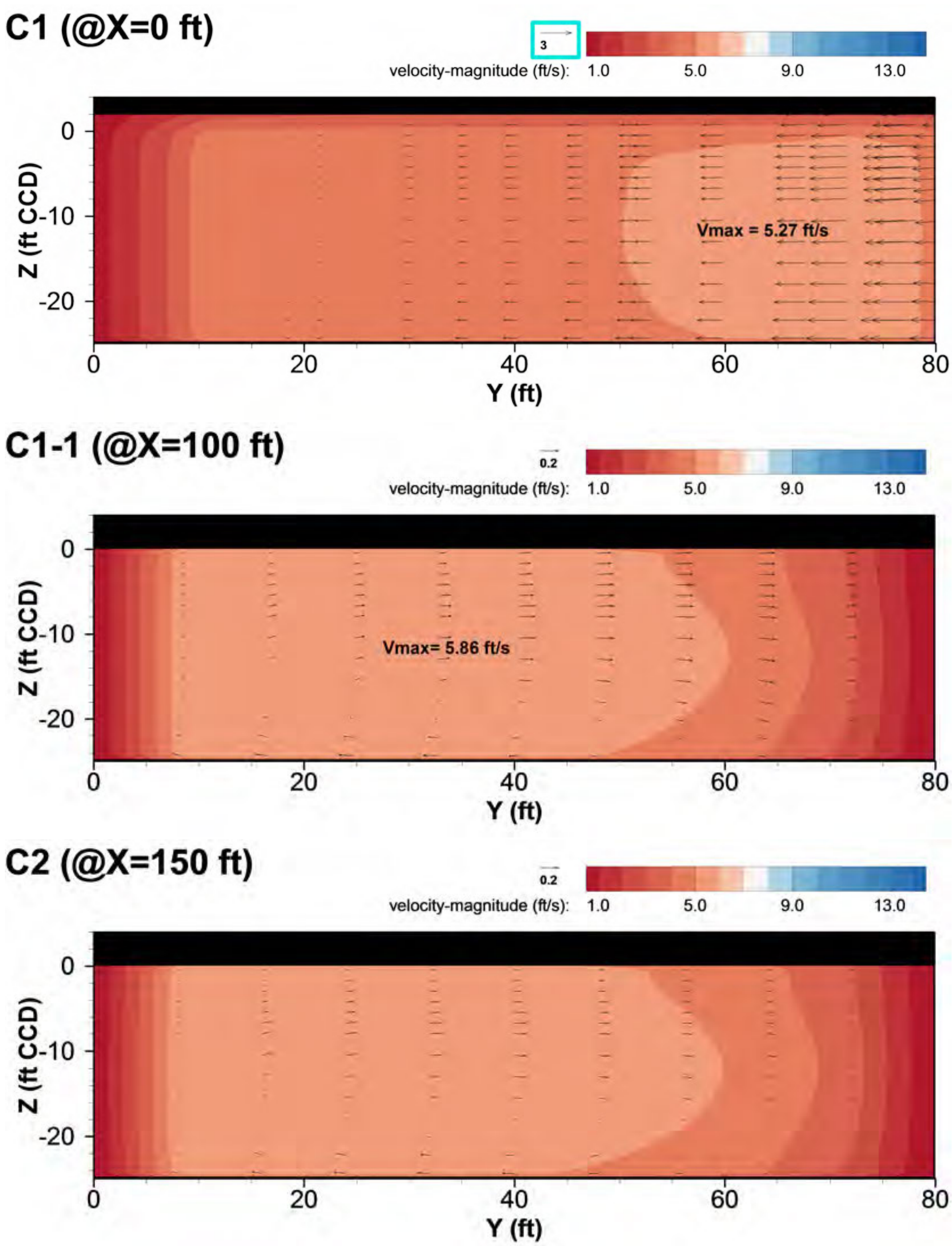


Figure A.11: Velocity Distribution with Streamline at Cross-Sections
(Case 1–Q_{lock} =11,200 cfs of steady flow, about half of flow discharge in Case 2)

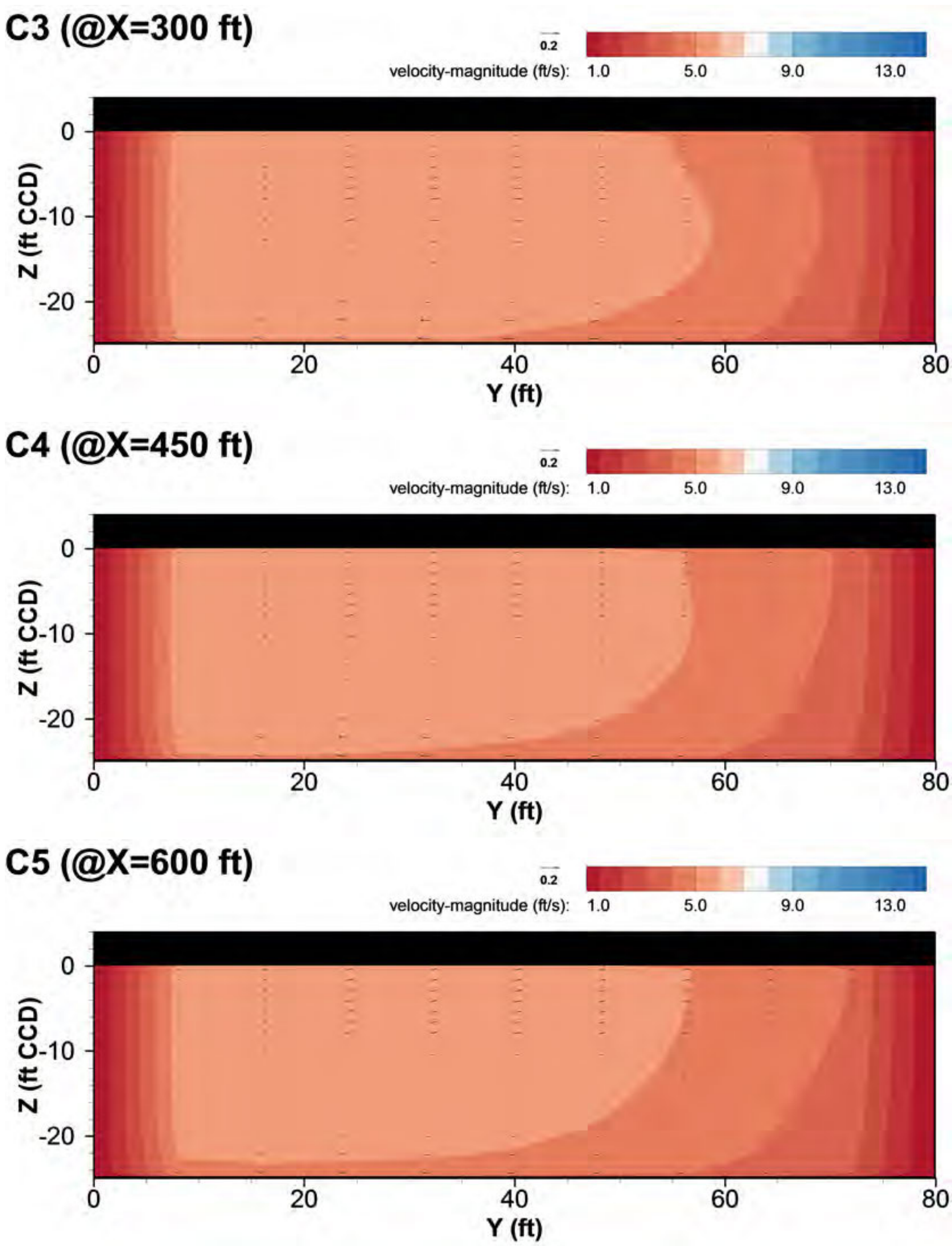


Figure A.12: Velocity Distribution with Streamline at Cross-Sections
(Case 1–Q_{lock} =11,200 cfs of steady flow, about half of flow discharge in Case 2)

B Velocity Distribution at Sluice Gates (Case 2 in Appendix A)

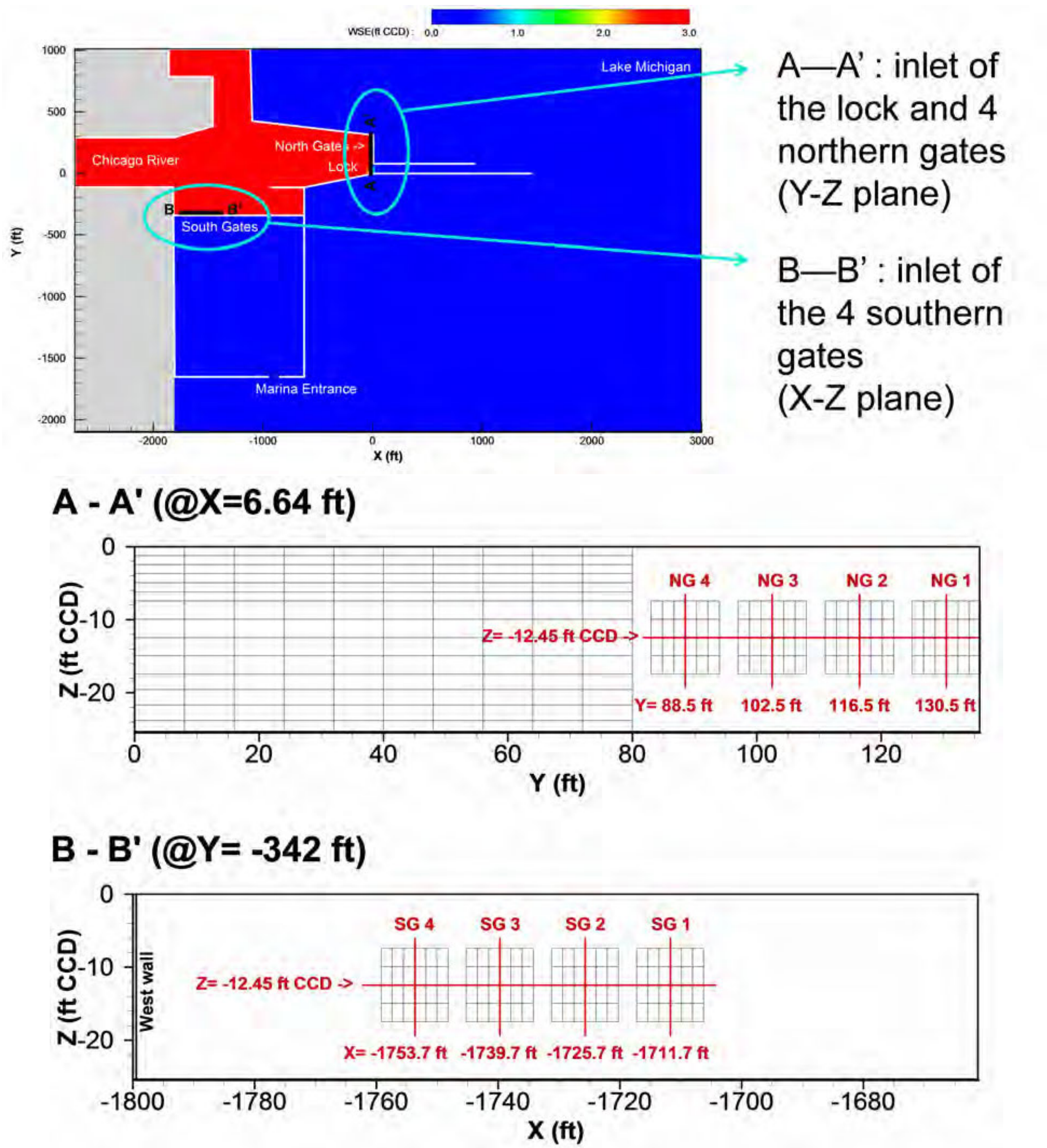


Figure B.1: Location of the hydraulic structures

B.1 Results

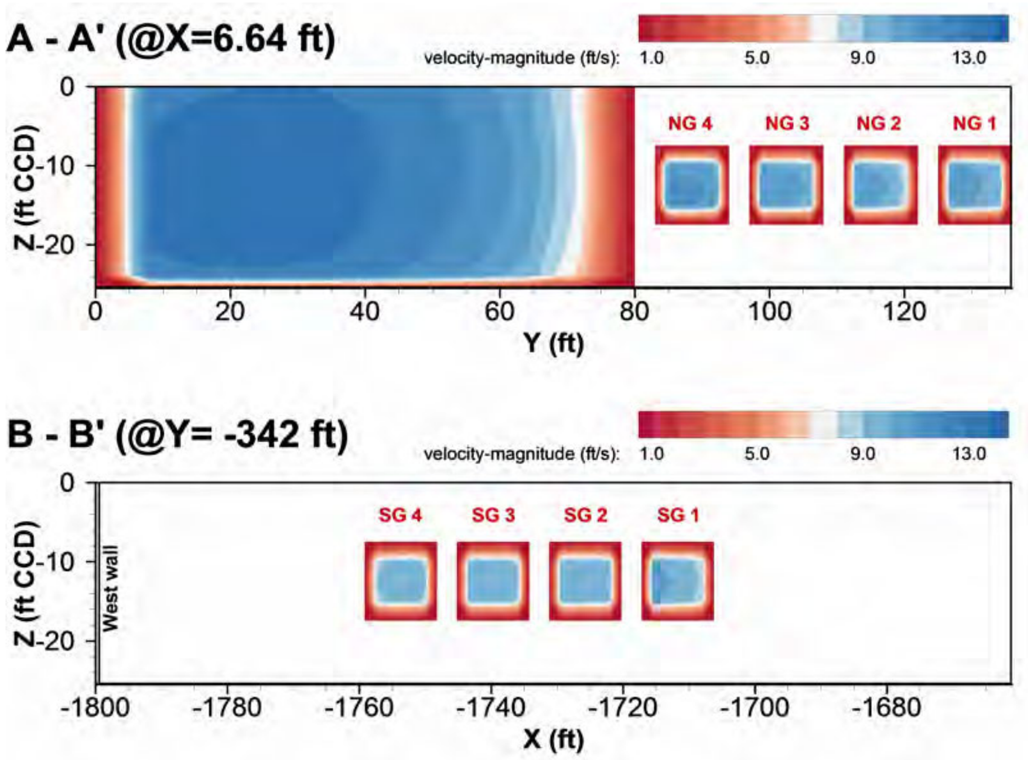


Figure B.2: Cross-sectional velocity distribution

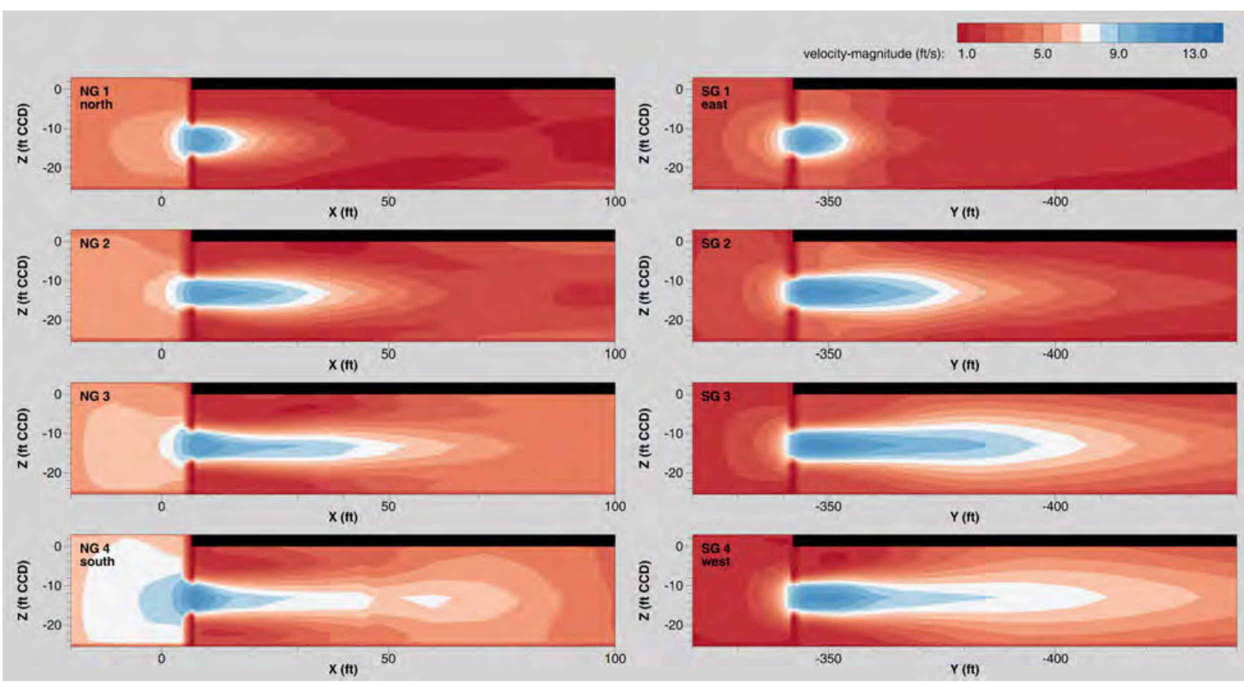


Figure B.3: Longitudinal-plane velocity distribution

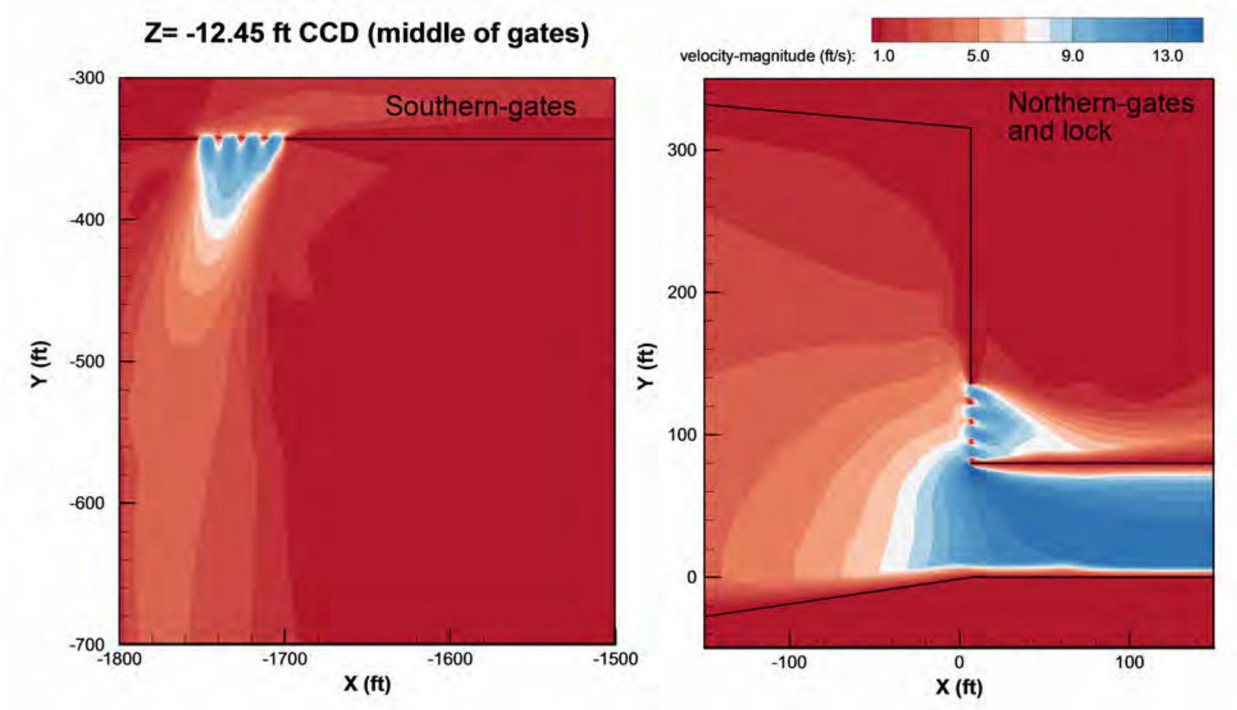


Figure B.4: XY-plane velocity distribution

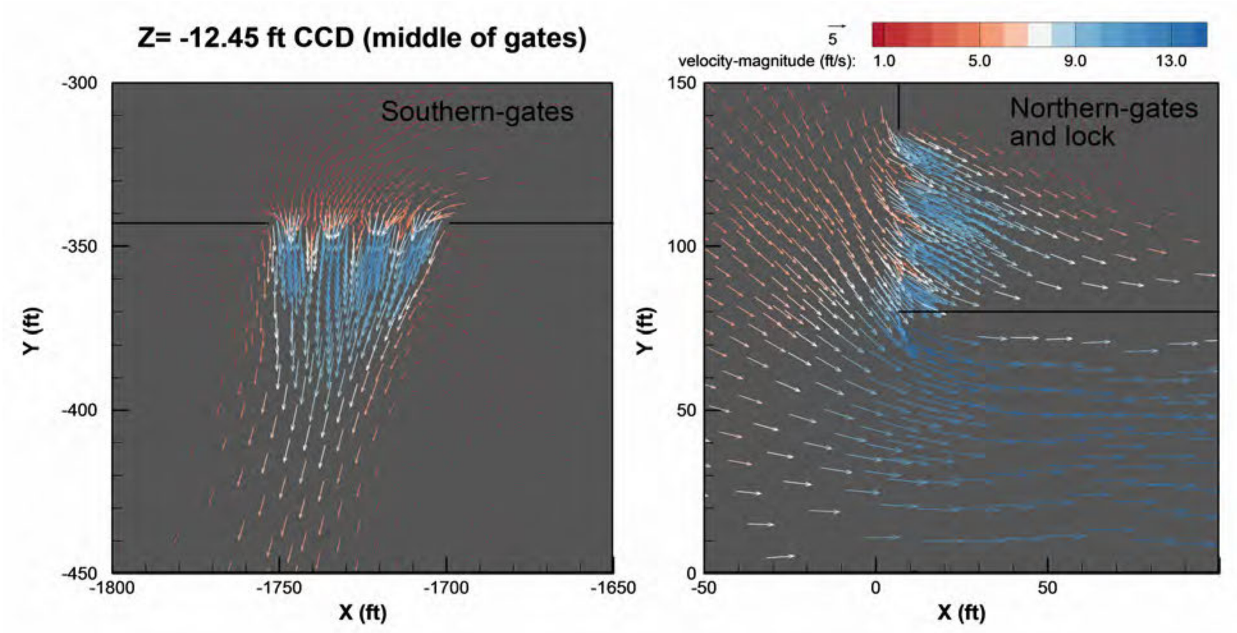


Figure B.5: XY-plane velocity vector distribution

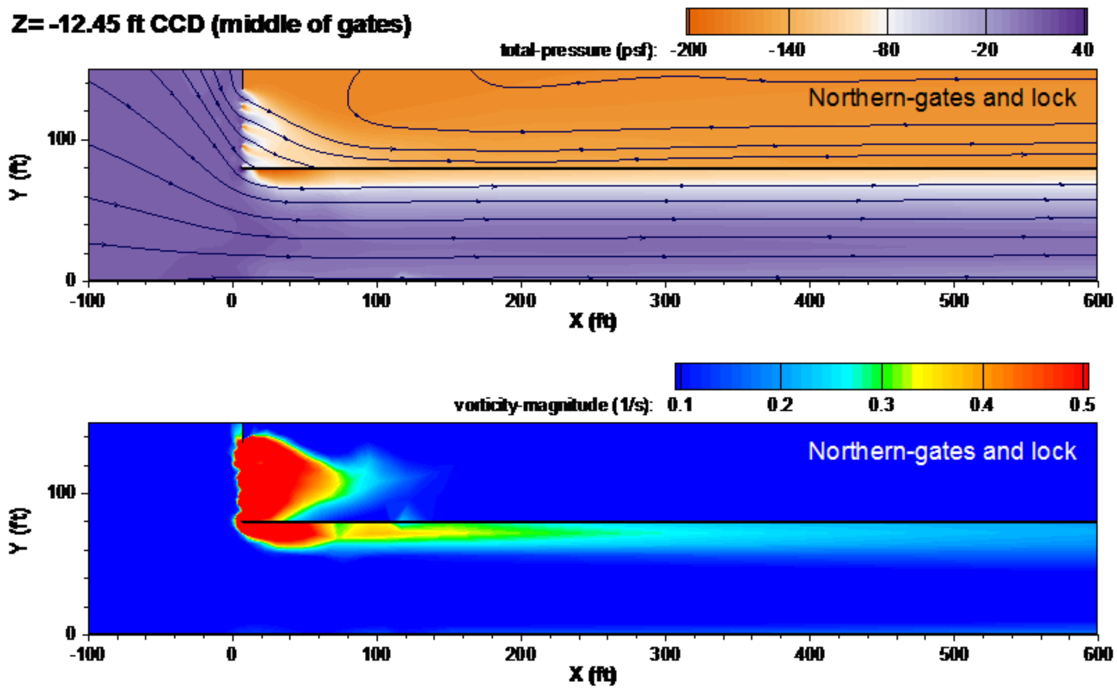


Figure B.6: Pressure and vorticity near lock

MINUTES OF THE MAY 20, 2003 MEETING WITH THE ARMY CORPS OF ENGINEERS, METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO, AND THE U.S. COAST GUARD

EXHIBIT H

INTEROFFICE MEMORANDUM

Metropolitan Water Reclamation District Of Greater Chicago

DEPARTMENT: Maintenance and Operations **DATE:** June 11, 2003

TO: Sergio E. Serafino, Supervising Civil Engineer

FROM: Patrick Connolly, AETPO 1

SUBJECT: Minutes of the May 20, 2003 Meeting with the Army Corps of Engineers and the US Coast Guard

The following summaries the discussion between personnel of the MWRD, the Chicago and Rock Island Districts of the Army Corps of Engineers and the Chicago office of the United States Coast Guard, which occurred May 20, 2003 at the main office of the MWRD. In attendance were:

Sergio Serafino, MWRD
Jim Vey, MWRD
Patrick Connolly, MWRD
Don Wadleigh, ACE
Patrick Wharry, ACE
Susanne Davis, ACE
Jim Stiman, ACE
Bob Balamot, ACE
Dave Vasner, ACE
Rick Granados, ACE
David Fish, USCG
Shannan Austin, USCG
Ken Brockhouse, USCG

Waterway Operations

The MWRD inquired if the Chicago River water elevation at the Chicago River Controlling Works (CRCW) can be maintained below –2.0' CCD during a non-run-off periods, as it takes hours to lower the elevation at CRCW in preparation for a run-off event, the preparation for a forecasted storm and during recovery of a storm. This request is based in the fact that current practice forces discretionary water to be wasted as navigational make-up restoring elevations to -2.0' CCD. In addition, it was inquired if the Cal-Sag junction limit of -4.0' CCD and/or the Lockport limit of -10.0' CCD could be lowered to ease operations during heavy rainfalls.

It was noted of the importance of maintaining a significant hydraulic gradient between the Wilmette Pumping Station (WPS) and CRCW, as flow from WPS must overcome the confluence of the North Shore Channel and discharge of the North Side water reclamation plant in order to prevent reversal at WPS and flooding. It was noted that the May 2003 rain event would have resulted in a reversal at WPS, if the elevation at CRCW had not been lowered to –3.0' CCD in anticipation of the storm.

It was agreeable between the Rock Island District (RIACE) and the Chicago District (CACE) of the Army Corps of Engineers and the MWRD that the river elevation at CRCW and O'Brien Locks would be maintained between 0.2' and 0.5' below the elevation of the lake when the lake elevation is below -2.0' CCD. However, when a low lake elevation would require the river elevation to be less than -3.0' CCD, approval must be received from both the CACE and RIACE.

It was agreeable to all parties, that during run-off periods and during preparation/recovery from a storm, the elevation at CRCW and O'Brien Locks may be operated between –2.0 to –3.0 CCD. However, an elevation of I–3.0' CCD or lower requires approval from both the CACE and RIACE.

The RIACE stated that upstream of the Cal-Sag junction there are shallow areas, which dictates maintaining the -4.0' CCD limit at the junction for navigational purposes. The RIACE has no current plans for dredging this area and dredging will only be performed if the lake level remains low. The USACE has set maximum ship draft at nine feet and therefore the -4.0' CCD limit must be maintained.

The United States Coast Guard (USCG) remains concerned about maintaining navigational depths as barges containing hazardous material that may have struck bottom are stopped and mandated to be dry-docked for inspection. Barges with non-hazardous cargo also have a potential for hull damage. In addition, they are concerned about elevation changes, which would cause barges to break away from their moorings.

The USCG proposed the possible development of a memo of agreement with the water carrier industry, which would halt river traffic during canal draw-down events and thereby eliminate the need to maintain navigational depths. The USCG was to discuss with the industry the feasibility of such an agreement, however it imagined such an agreement would require political steering.

The USCG and RIACE are to review riverbed surveys to locate shallow areas, which would require dredging to maintain navigational depth, if the Cal-Sag junction was to be below -4.0'CCD. However, for the USACE to permit a change to the current limit at the Cal-Sag junction of -4.0' CCD, a policy change would be required at the Divisional level of the USACE. Unless both the USACE policy change is approved and the USCG can develop an agreement with the water carrier industry, the Cal-Sag minimum elevation of -4.0' CCD is inflexible.

The RIACE is calibrating a predictive model for the canal elevation, which they think will be useful in analyzing this question. To assist them in the calibration, they requested access to real time elevation and rain gauge data from the MWRD. The MWRD will investigate the possibility of this remote access.

It was recommended that the USACE and USCG investigate the impact of extended low river elevations on navigation, which occurred during the 1993 Chicago flood.

The CACE is reviewing a study on navigational makeup water. The study appears to show that canal elevations of -3.0' CCD at the O'Brien Lock and -4.0' CCD at Cal-Sag junction can recover acceptably with natural recharge and would not require navigational make-up water. The CACE did not object to the findings of the study. Additionally, it is understood by the CACE, that the Illinois Department of Natural Resources (IDNR) is reviewing the study in an effort to allocate additional diversionary water for domestic use.

The elevation limit at Lockport is set at -10.0' CCD in order to maintain a required minimum one foot depth over the lock sill and therefore is firm.

<u>Notices and Warnings</u>

The CACE issues a warning to watercraft when the elevation at CRCW is less than -2.0' CCD. Additionally, the US Geological Survey website publishes real time flow rate data for the river system and the RIACE is installing an additional elevation gauge on the DesPlaines River at 16th Street.

The MWRD issues a warning to a list of river-based industries, if canal flow is increased over 7,000 cfs. The USCG has not been receiving the MWRDGC warning. The MWRD will include the USCG in the notification list when channel discharge exceeds 7,000 cfs. The RIACE questioned if the MWRD issue updates for each flow increase over 7,000 cfs. The MWRD Dispatchers issue these updates. The Lockport Lockmaster reported that he does receive the updates. RIACE insisted on the importance of notifying the Lockmaster at the Brandon Lock of flow changes.

The USCG broadcasts a "Mariner's Warning" during hazardous navigating conditions, but does not issue a general stop order to water carriers. Currently, ship captains decide when conditions warrant docking.

<u>Stoppage of Lockage</u>

The MWRDGC has, in the past, ordered a stop to lockage at CRCW when the lake elevation is below the river elevation in order to prevent reversal to the lake. It was questioned why the O'Brien Lock continues to operate, when the CRCW lock is halted. The RIACE stated they are not authorized to halt lockage as long as there is water over the lock sill. In addition, the USACE is obligated by law to lock any vessel at the request of the captain, regardless of the navigational conditions.

It was agreed, however, that the MWRDGC may order a stop to lockage. For the CRCW Lock, the MWRD is to notify the CRCW Lockmaster of the order. The CRCW Lockmaster will follow the MWRD order and inform his supervision at the CACE. For the O'Brien Lock, the MWRD will request the RIACE to issue the order to the O'Brien Lockmaster, who will accept the order only through his line of supervision. The USCG is to be notified by the responsible USACE District when lockage has been stopped at any lock.

Miscellaneous

The RIACE is to perform an underwater inspection of the right decent wall of the Sanitary and Shipping Canal by the Lockport powerhouse and the pit gate draft tubes at the Lockport powerhouse to identify any deterioration of the structures.

Patrick Connolly
AETPO 1

1045a

J. Vay[illegible]	MWRD	
[illegible]	MWRD	
David Fish	USCG	630 986 2137
SHANNAN AUSTIN	USCG	630 986 2175
KEN BROCKHOUSE	USCG	630 986-2175
Don Wadleigh	Corps-Chicago	312-846-5474
Bob Balamut	Corps-Rock Island	773-646-2183
PATRICK WHAREY	COE-LOCKPORT Lock	815-838-0536
Dave Vasner	COE-Rock Island	309-676-4601 x217
Suzanne Davis	COE-Chicago	312-846-5510
Rick GRANADOS	COE-ROCK ISLAND DIST	309/676-4601 x 210
Jim Stiman	COE-Rock Island	(309) 794-5849
SERGIO SERAFINO	SUPERVISING CIVIL ENG	312 751 5107

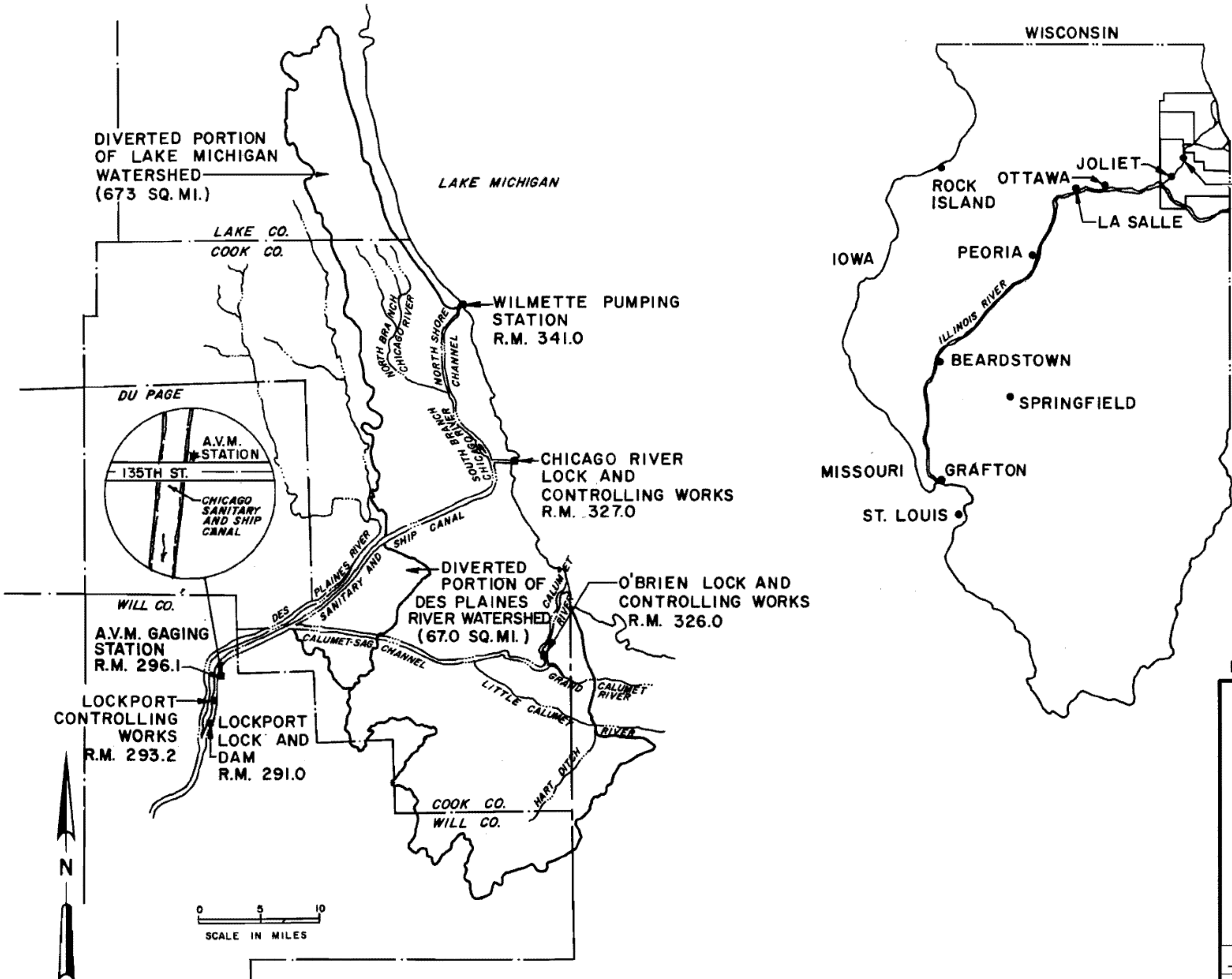


PLATE 2-1

UPPER MISSISSIPPI RIVER BASIN
ILLINOIS WATERWAY

VICINITY AND LOCATION OF LOCKPORT LOCK AND WATERSHED

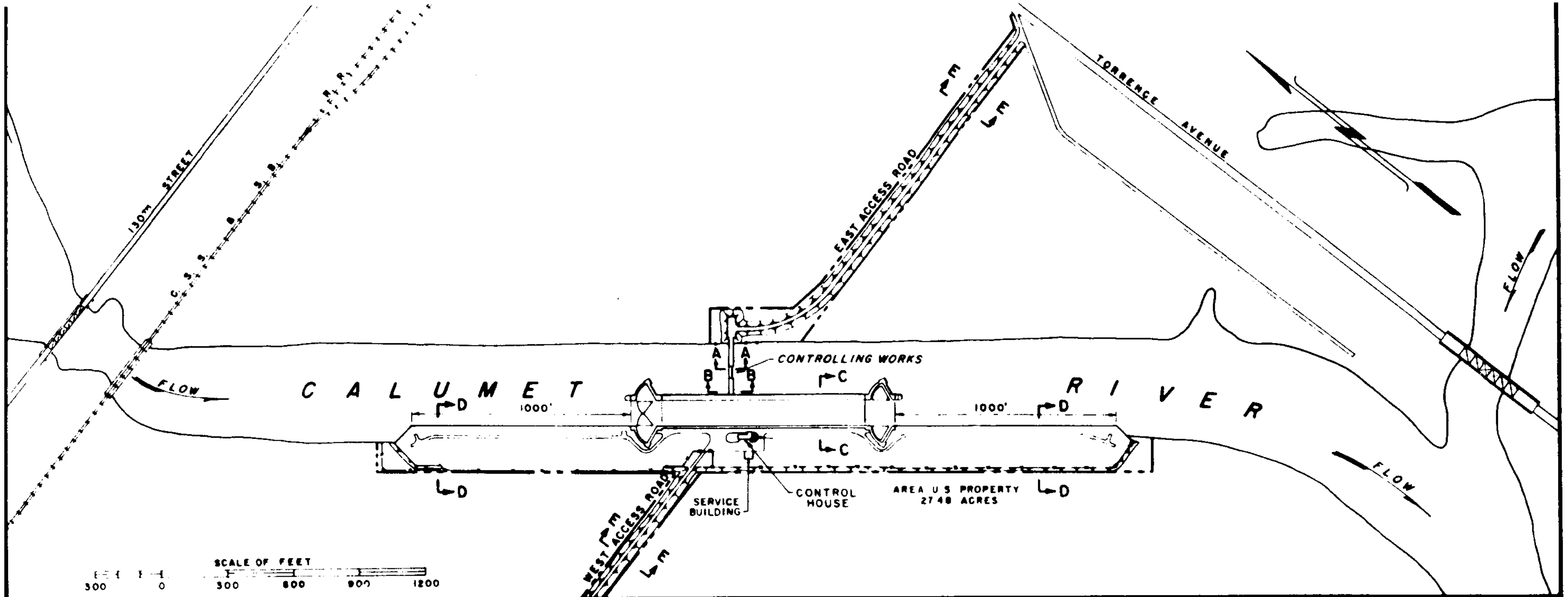
CORPS OF ENGINEERS
ROCK ISLAND, ILLINOIS

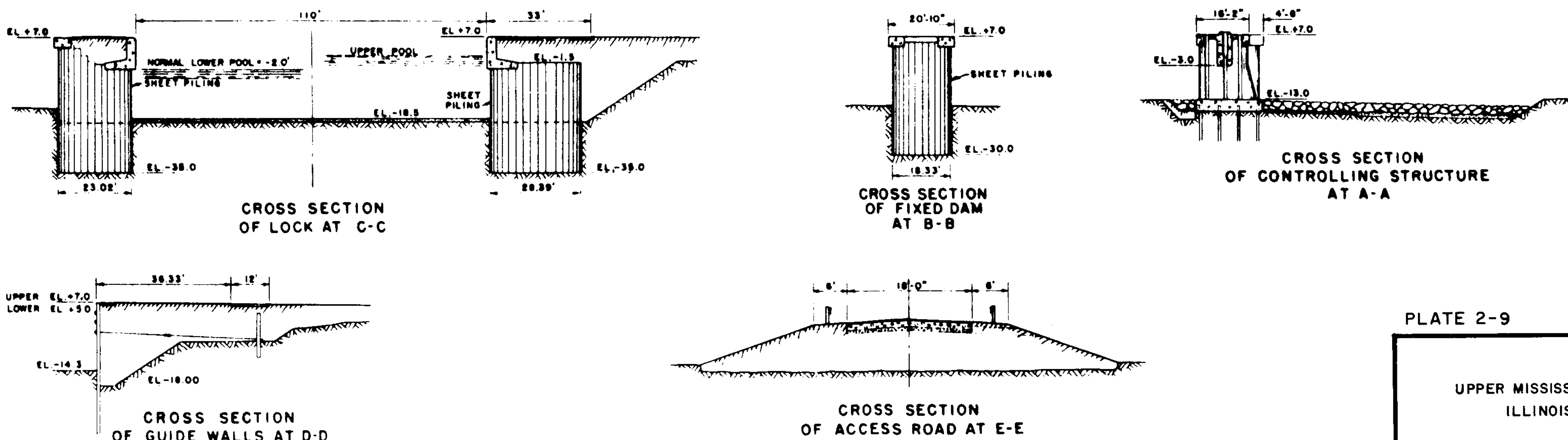
ROCK ISLAND DISTRICT
1985

THOMAS J. O'BRIEN LOCK & CONTROLLING WORKS

STRUCTURE DATA

Lock:
- Available Length 1,000'
- Clear Width 110'
- Sector Gate Sills El.-17.00 C.C.D.





ELEVATIONS SHOWN ON CROSS SECTIONS REFER TO CHICAGO CITY DATUM.
0.0 ft. CCD = 579.5 N.G.V.D.

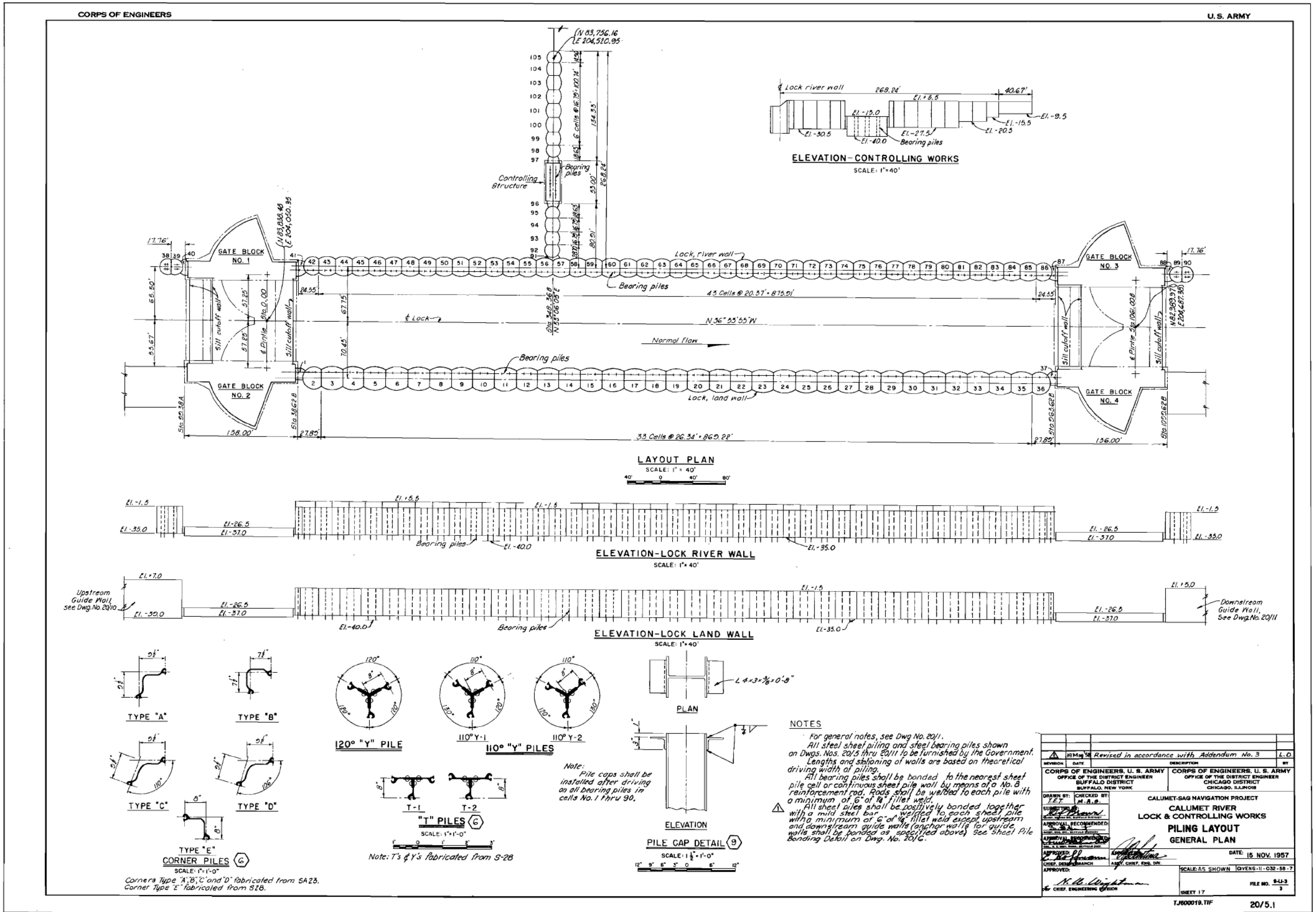
PLATE 2-9

UPPER MISSISSIPPI RIVER BASIN
ILLINOIS WATERWAY

THOMAS J. O'BRIEN
LOCK AND CONTROLLING WORKS
PLAN AND SECTIONS

CORPS OF ENGINEERS
ROCK ISLAND, ILLINOIS

ROCK ISLAND DISTRICT
SEPTEMBER 1985


CORPS OF ENGINEERS
U.S. ARMY
LAYOUT PLAN
SCALE: 1" = 40'
GATE BLOCK NO. 1
GATE BLOCK NO. 2
GATE BLOCK NO. 3
GATE BLOCK NO. 4
Controlling Structure
Bearing piles
Lock, river wall
Lock, land wall
Sill cutoff wall
℄ Lock
℄ Pintle
Normal flow
N 36° 55' 55" W
43 Cells @ 20.37' = 875.91'
33 Cells @ 26.34' = 869.22'
ELEVATION-CONTROLLING WORKS
SCALE: 1" = 40'
ELEVATION-LOCK RIVER WALL
SCALE: 1" = 40'
ELEVATION-LOCK LAND WALL
SCALE: 1" = 40'
Upstream Guide Wall, See Dwg. No. 20/10
Downstream Guide Wall, See Dwg. No. 20/11
TYPE "A"
TYPE "B"
TYPE "C"
TYPE "D"
TYPE "E"
CORNER PILES
SCALE: 1" = 1'-0"
Corners Type "A", "B", "C" and "D" fabricated from SA23.
Corner Type "E" fabricated from S28.
120° "Y" PILE
110° Y-1
110° Y-2
110° "Y" PILES
T-1
T-2
"T" PILES
SCALE: 1" = 1'-0"
Note: T's & Y's fabricated from S-28
Note: Pile caps shall be installed after driving on all bearing piles in cells No. 1 thru 90.
PLAN
ELEVATION
PILE CAP DETAIL
SCALE: 1 1/2" = 1'-0"
L 4×3×5/16×0'-8"
NOTES
For general notes, see Dwg No. 20/1.
All steel sheet piling and steel bearing piles shown on Dwgs. Nos. 20/5 thru 20/11 to be furnished by the Government.
Lengths and stationing of walls are based on theoretical driving width of piling.
All bearing piles shall be bonded to the nearest sheet pile cell or continuous sheet pile wall by means of a No. 8 reinforcement rod. Rods shall be welded to each pile with a minimum of 6" of 1/4" fillet weld.
All sheet piles shall be positively bonded together with a mild steel bar welded to each sheet pile with a minimum of 6" of 1/4" fillet weld except upstream and downstream guide walls (anchor walls for guide walls shall be bonded as specified above). See Sheet Pile Bonding Detail on Dwg. No. 20/6.
Revised in accordance with Addendum No. 3
CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER
BUFFALO DISTRICT
BUFFALO, NEW YORK
CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER
CHICAGO DISTRICT
CHICAGO, ILLINOIS
CALUMET-SAG NAVIGATION PROJECT
CALUMET RIVER
LOCK & CONTROLLING WORKS
PILING LAYOUT
GENERAL PLAN
DATE: 15 NOV. 1957
SCALE: AS SHOWN
SHEET 17
TJ600019.TIF
20/5.1

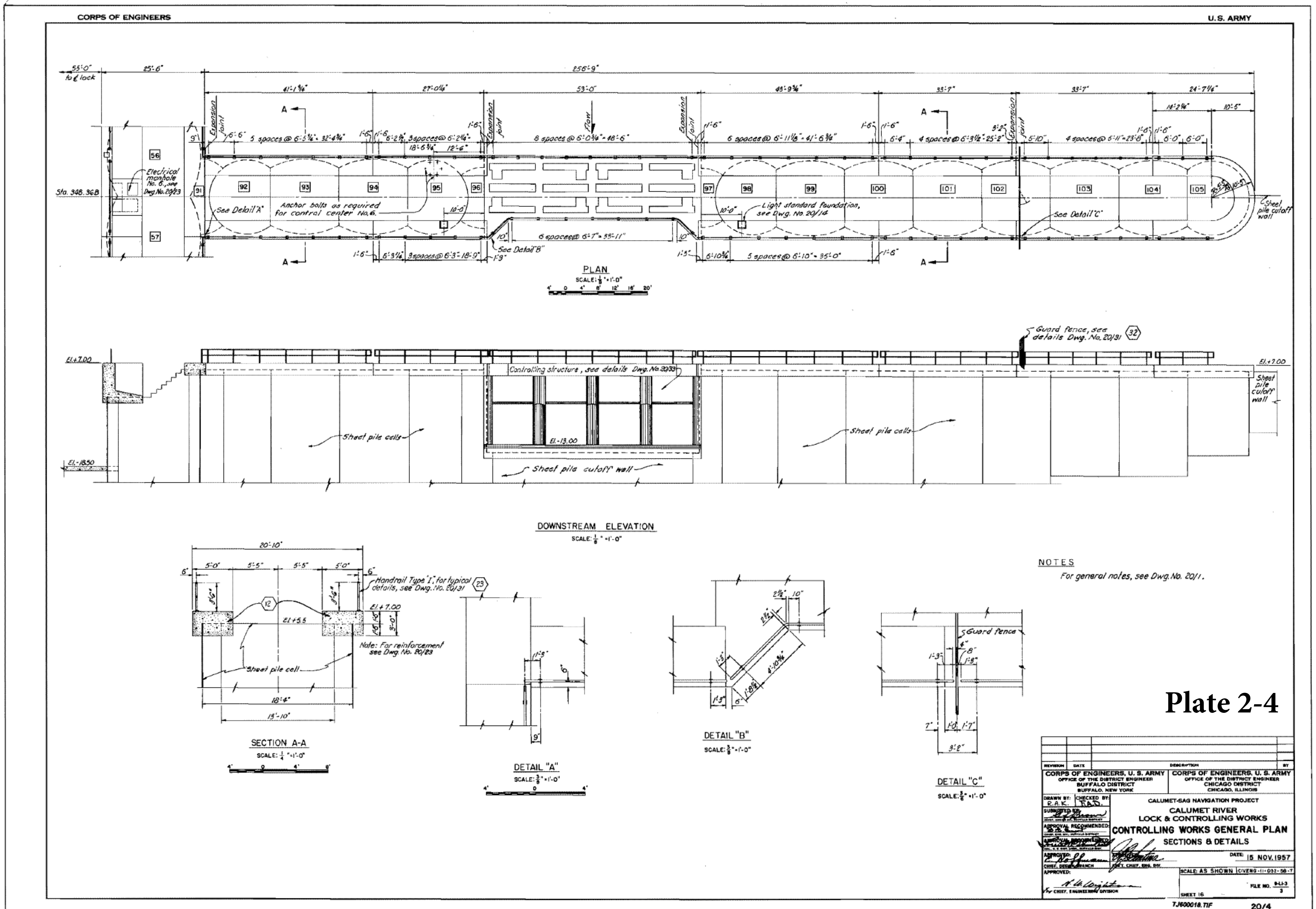
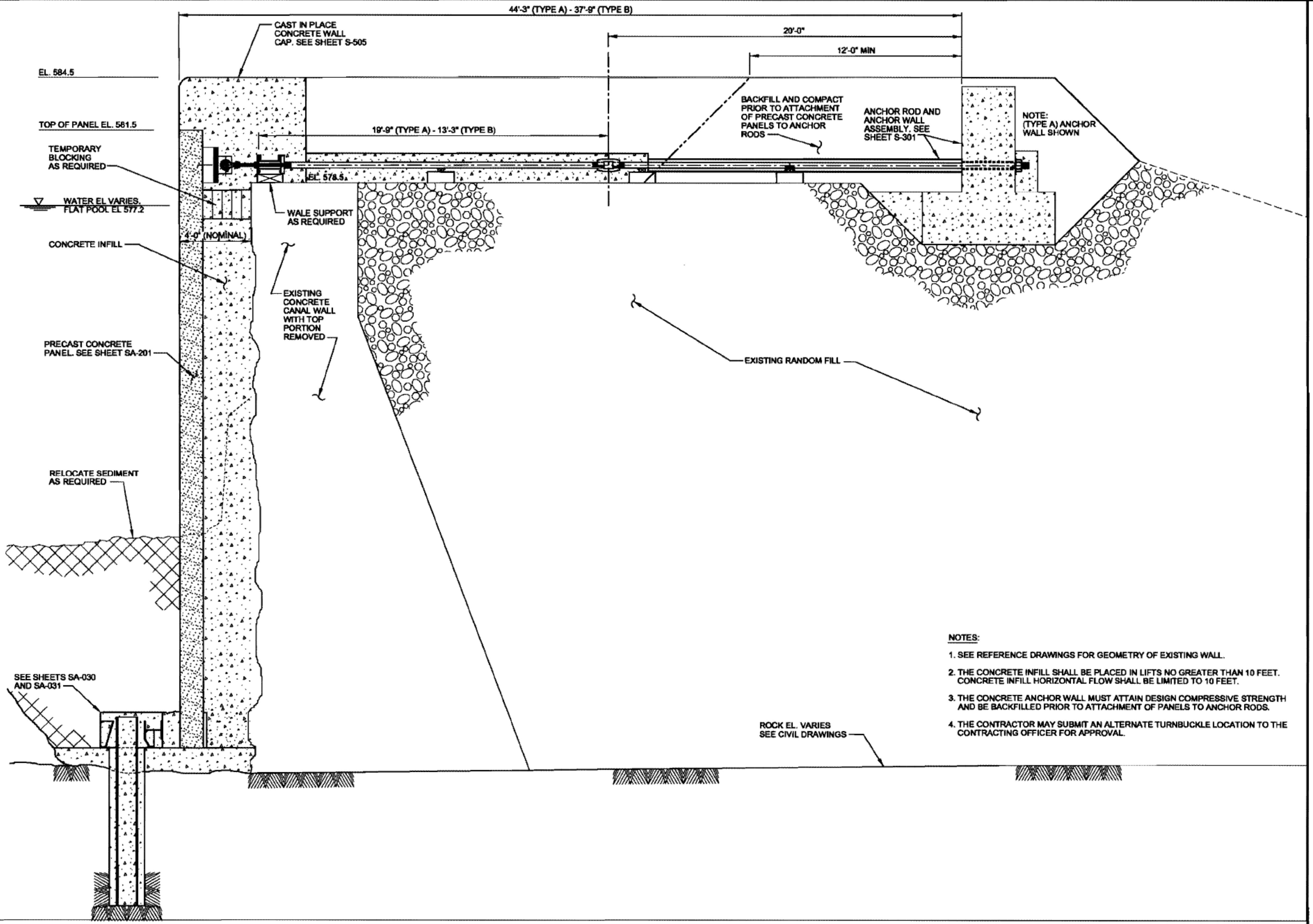


Plate 2-4

10/22 - Changed concrete wall from 2'-7½" to 3'-0, added note to Sec. A-A

PLATE 7



NOTES:

1. SEE REFERENCE DRAWINGS FOR GEOMETRY OF EXISTING WALL.
2. THE CONCRETE INFILL SHALL BE PLACED IN LIFTS NO GREATER THAN 10 FEET. CONCRETE INFILL HORIZONTAL FLOW SHALL BE LIMITED TO 10 FEET.
3. THE CONCRETE ANCHOR WALL MUST ATTAIN DESIGN COMPRESSIVE STRENGTH AND BE BACKFILLED PRIOR TO ATTACHMENT OF PANELS TO ANCHOR RODS.
4. THE CONTRACTOR MAY SUBMIT AN ALTERNATE TURNBUCKLE LOCATION TO THE CONTRACTING OFFICER FOR APPROVAL.

TYPICAL NORMAL WALL SECTION

TYPE B SHOWN

4 0 4
SCALE IN FEET

US Army Corps of Engineers ®
Rock Island District

Symbol	Description	Date	Approved
	Revisions		

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ROCK ISLAND, ILLINOIS

Designed By: CHJ/BTJ	Date: 10 JUNE 2009	
Drawn By: RWS	Scale: AS SHOWN	
Checked By: CHJ	Project Code: LP 22	
Reviewed By: FRJ	Solicitation Number: W912EK-09-R-0065	

ILLINOIS WATERWAY
LOCKPORT LOCK
LOCKPORT, ILLINOIS
LOCKPORT POOL MAJOR REHAB
STAGE III CANAL WALLS

TYPICAL WALL SECTION NORMAL ALTERNATE DESIGN

Sheet Reference Number:
SA-103
Sheet 155 of 189

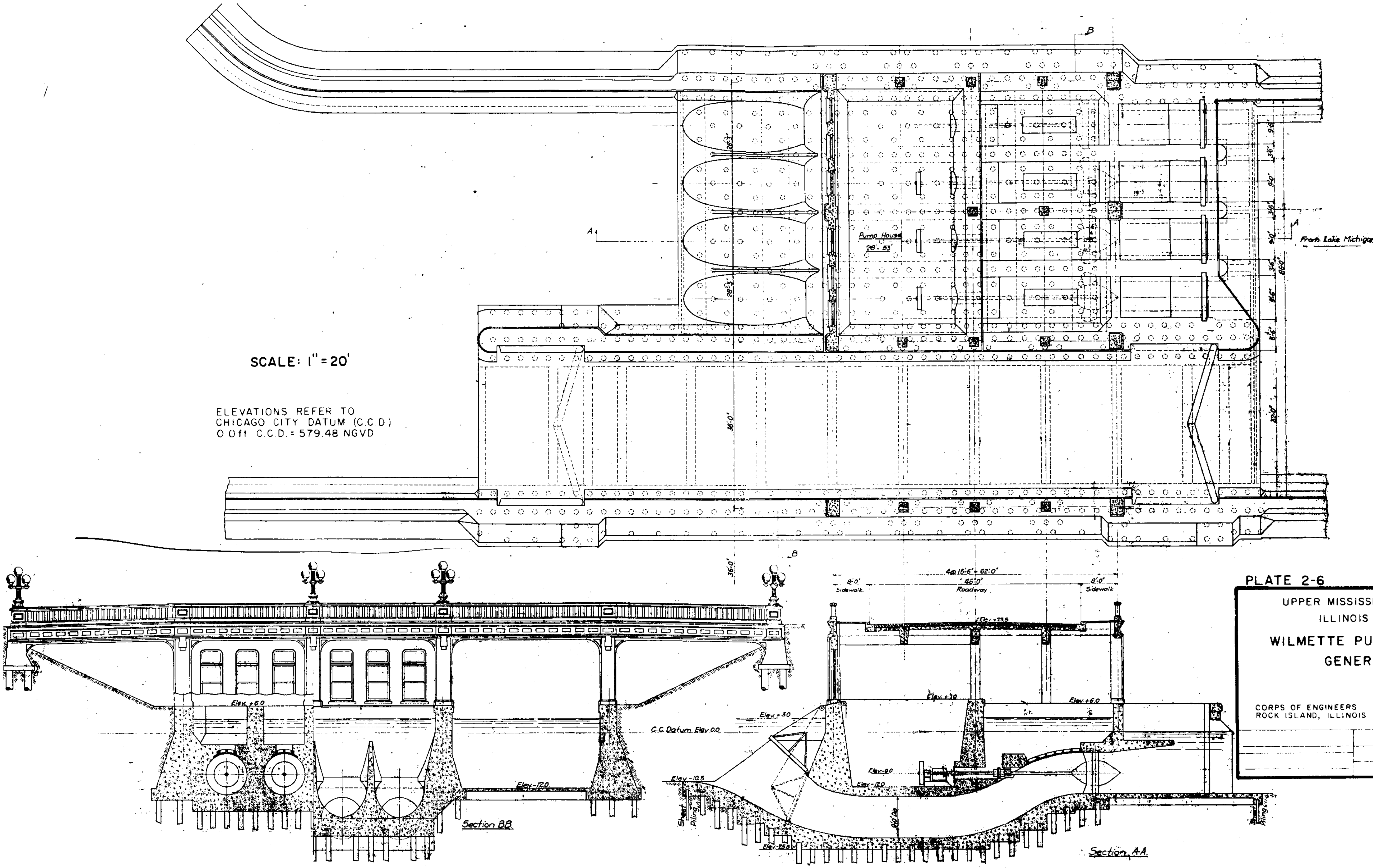


PLATE 2-6

UPPER MISSISSIPPI RIVER BASIN
ILLINOIS WATERWAY

WILMETTE PUMPING STATION
GENERAL PLAN

CORPS OF ENGINEERS
ROCK ISLAND, ILLINOIS

ROCK ISLAND DISTRICT
SEPTEMBER 1985

wc-466

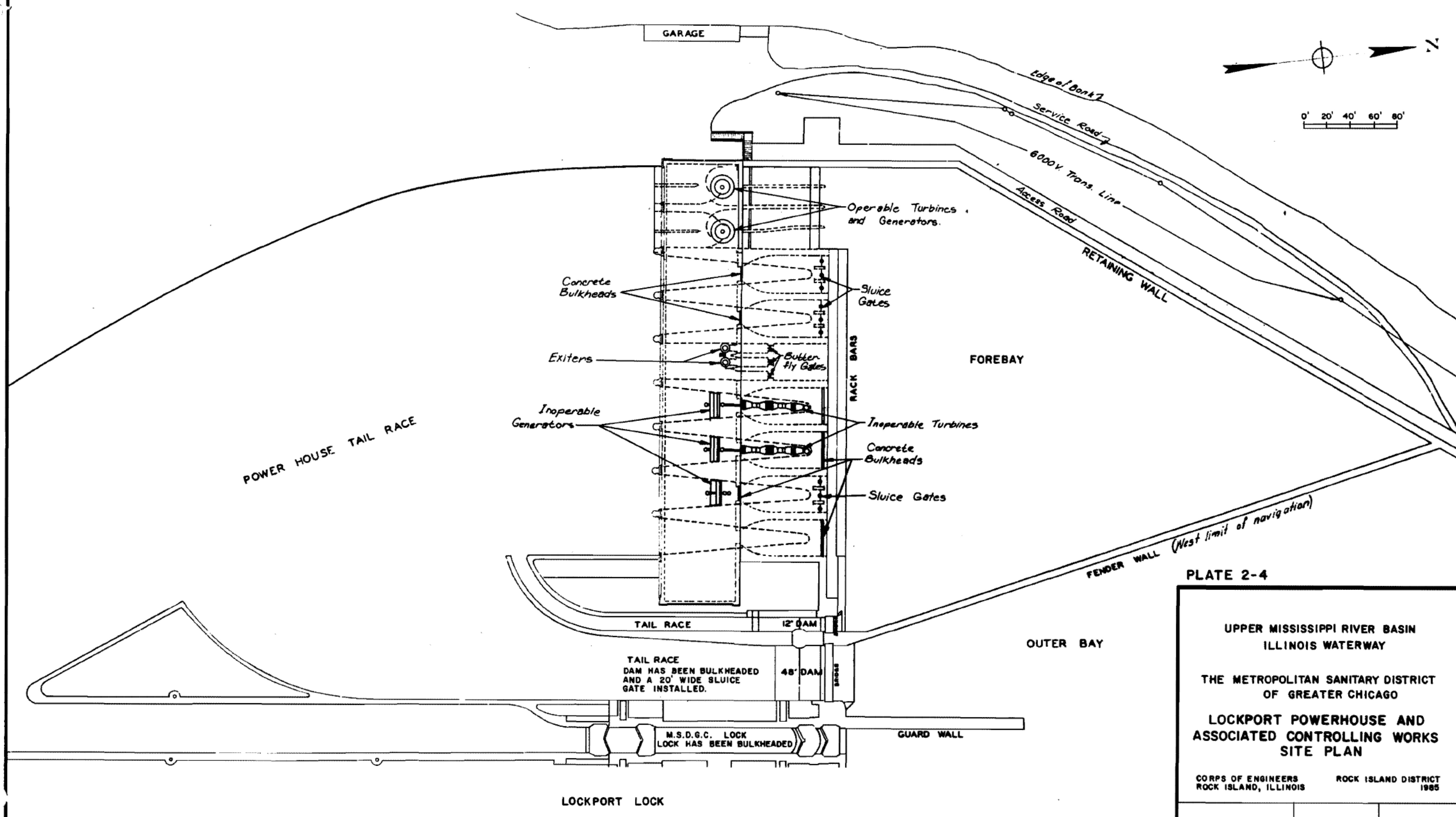


PLATE 2-4

UPPER MISSISSIPPI RIVER BASIN
ILLINOIS WATERWAY

THE METROPOLITAN SANITARY DISTRICT
OF GREATER CHICAGO

LOCKPORT POWERHOUSE AND ASSOCIATED CONTROLLING WORKS SITE PLAN

CORPS OF ENGINEERS
ROCK ISLAND, ILLINOIS

ROCK ISLAND DISTRICT
1985

WC-405

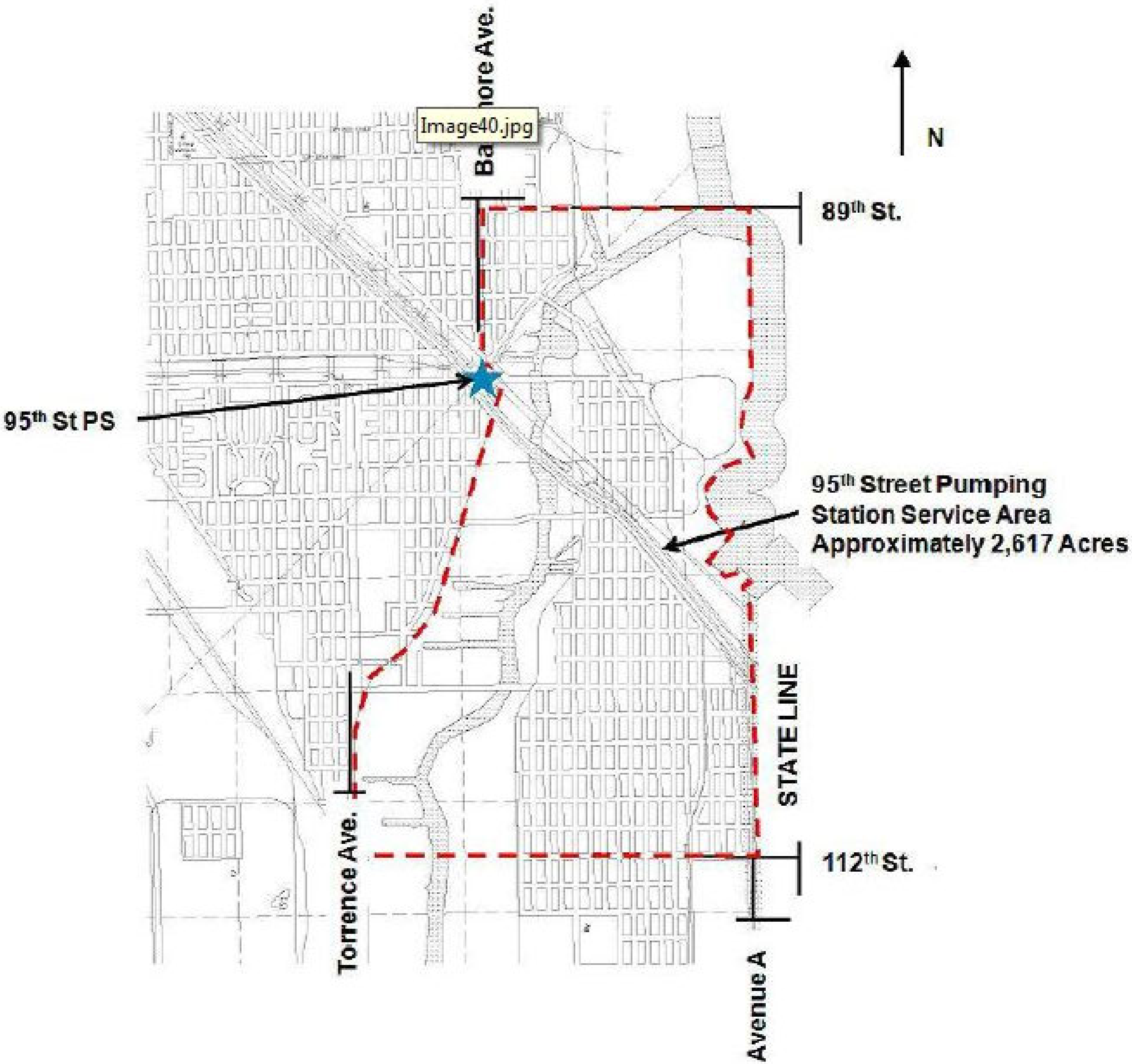
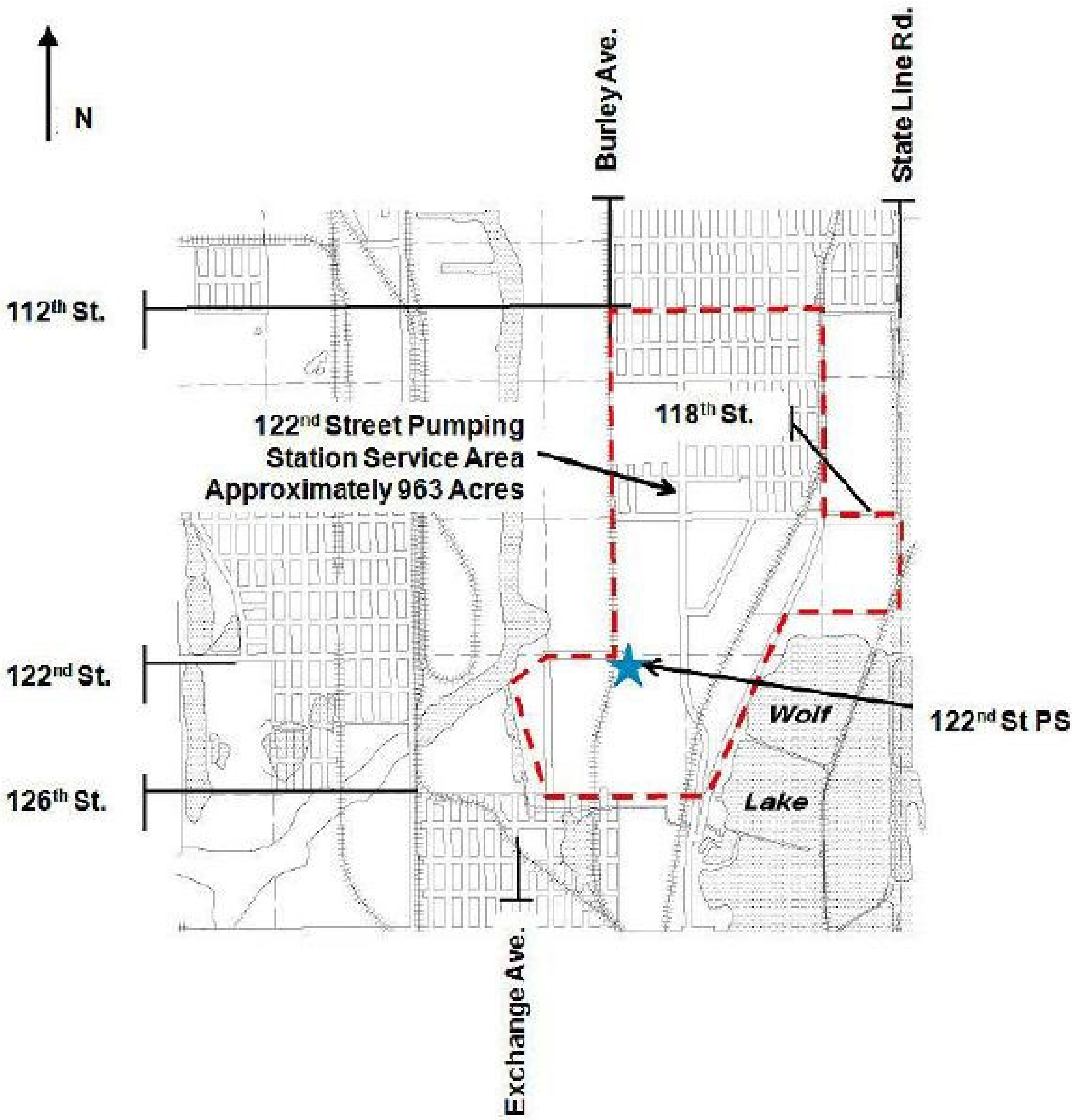
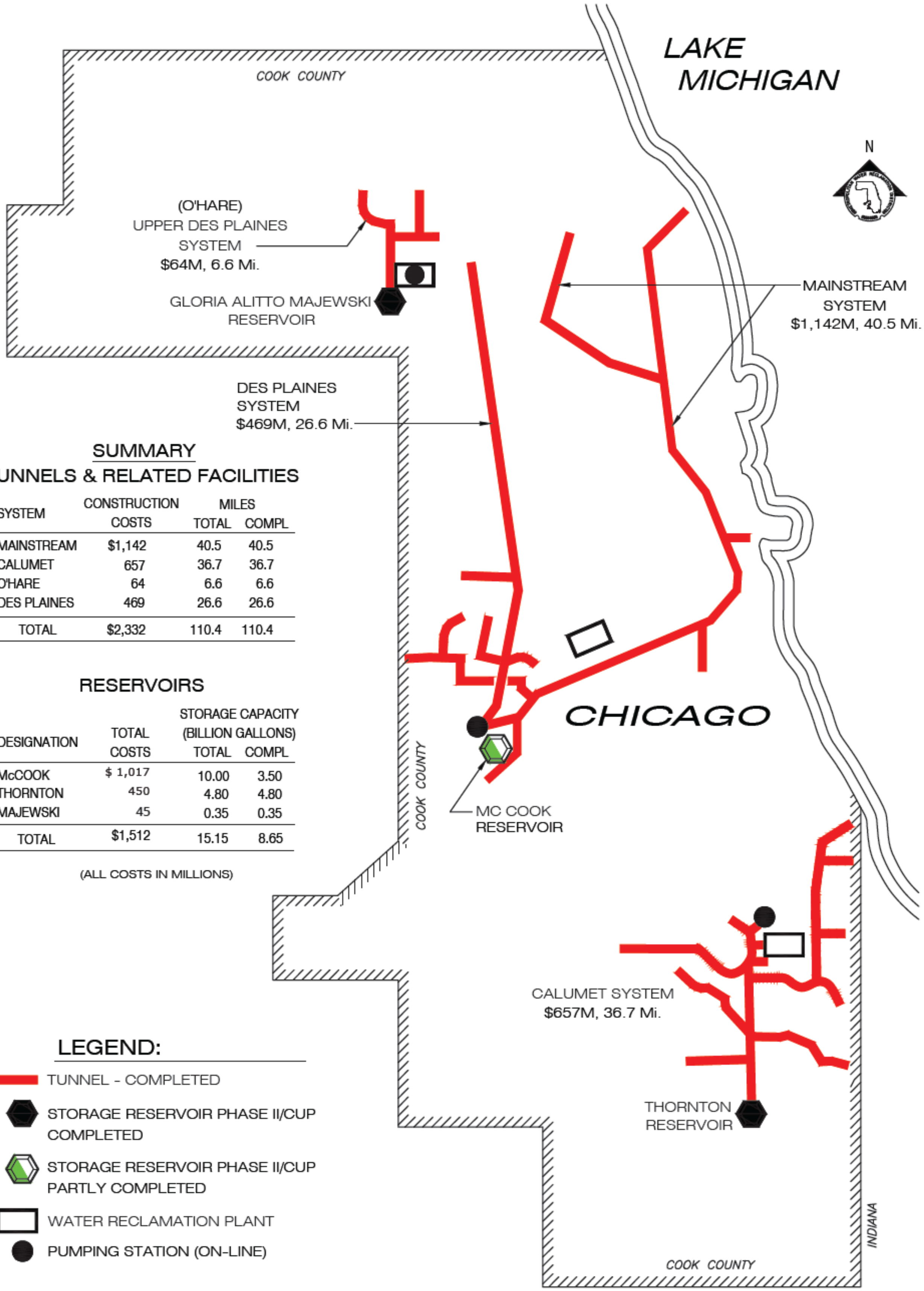


Image40.jpg
Ba more Ave.
N
89th St.
95th St PS
95th Street Pumping
Station Service Area
Approximately 2,617 Acres
STATE LINE
Torrence Ave.
112th St.
Avenue A


N
Burley Ave.
State Line Rd.
112th St.
118th St.
122nd Street Pumping
Station Service Area
Approximately 963 Acres
122nd St.
122nd St PS
Wolf
Lake
126th St.
Exchange Ave.



SUMMARY

TUNNELS & RELATED FACILITIES

SYSTEM	CONSTRUCTION COSTS	MILES TOTAL	MILES COMPL
MAINSTREAM	$1,142	40.5	40.5
CALUMET	657	36.7	36.7
O'HARE	64	6.6	6.6
DES PLAINES	469	26.6	26.6
TOTAL	$2,332	110.4	110.4

RESERVOIRS

DESIGNATION	TOTAL COSTS	STORAGE CAPACITY (BILLION GALLONS) TOTAL	STORAGE CAPACITY (BILLION GALLONS) COMPL
McCOOK	$ 1,017	10.00	3.50
THORNTON	450	4.80	4.80
MAJEWSKI	45	0.35	0.35
TOTAL	$1,512	15.15	8.65

(ALL COSTS IN MILLIONS)

LEGEND:

- TUNNEL - COMPLETED
- STORAGE RESERVOIR PHASE II/CUP COMPLETED
- STORAGE RESERVOIR PHASE II/CUP PARTLY COMPLETED
- WATER RECLAMATION PLANT
- PUMPING STATION (ON-LINE)

TUNNEL and RESERVOIR PLAN PROJECT STATUS

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO
ENGINEERING DEPARTMENT
COLLECTION SYSTEMS/TARP KMF/JJK

Plate 2-10

USACE T. J. O’Brien Lock Real Estate Ownership

Summary of Thomas J. O’Brien Lock and Dam Projects

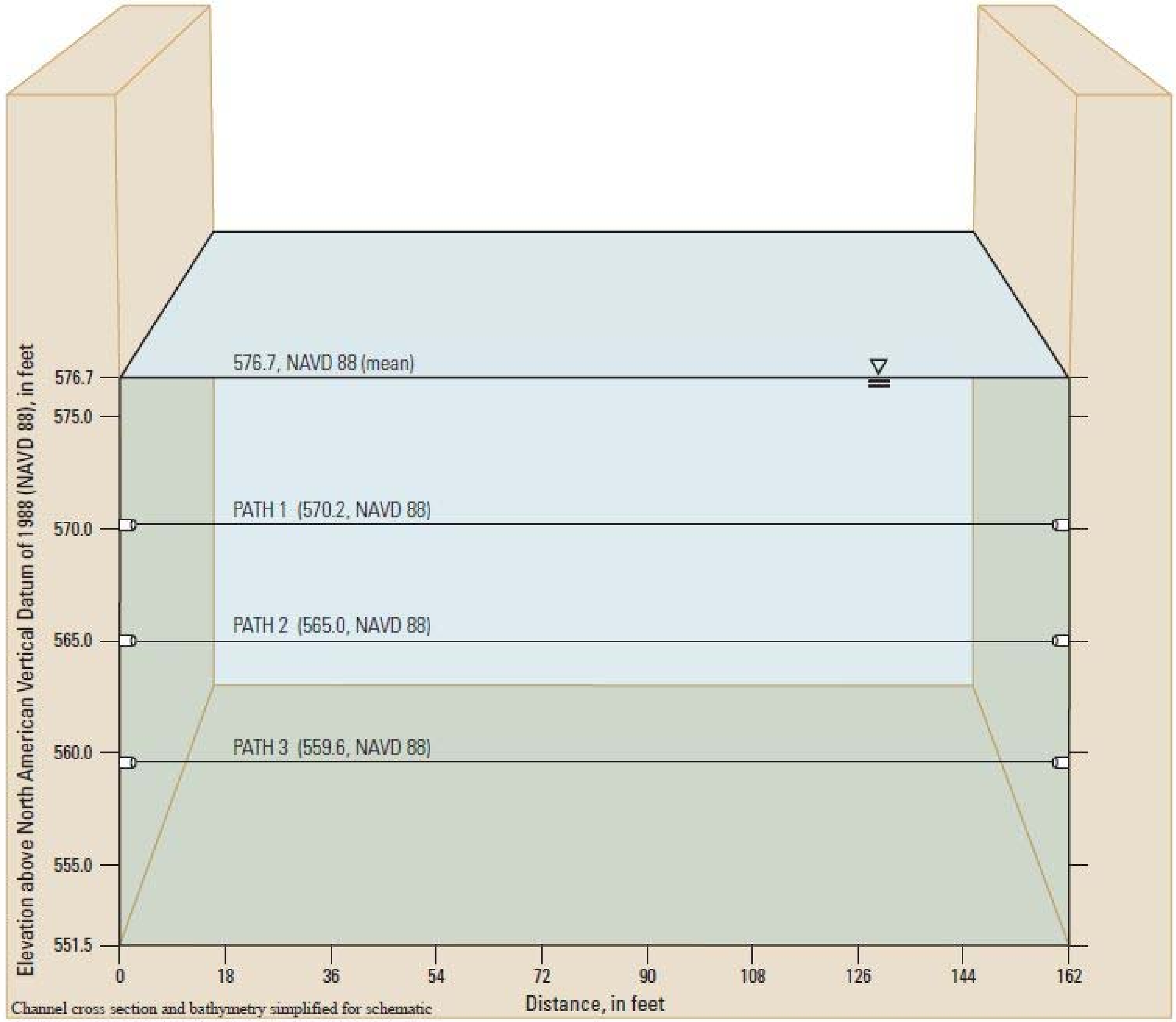
Significant remedial measures for TJ O’Brien L&D are listed below.

Updated January 2024.

- 1970: The bituminous pavement areas were resurfaced and a visitor parking area and comfort station were constructed.
- 1981: The maintenance building was built.
- 1986: New culvert slide valve operators were installed.
- 1988: A new radio antenna was installed.
- 1989: A new fuel tank was installed.
- 1990: The transformer replacement was completed.
- 1991: The fuel tank replacement was completed.
- 1992: The access road was resurfaced and the electrical feeder line was replaced.
- 1994: A new electrical feeder line was installed.
- 1998 New emergency generator installed.
- 2005: Security fence upgrades were completed.
- 2010: Main controlling house HVAC upgrade was completed.
- 2012: Riprap was placed downstream of the controlling works on the riverside of the river wall.
- 2015: The sector gates were blasted and painted during the 2015 dewatering. Sector gate pintles and top hinge pins were replaced, sector gate composite timbers were installed, and existing cathodic system removed. Bottom gate seals and vertical gate seals were replaced. New bubbler system piping was installed.
- 2016: Contract# W912EK-15-C-0043: Electrical service upgrade, bubbler system compressors with pre-engineered building enclosures, new transformer and meter, ATS, switchgear pre-engineered building, installation of concrete foundation slabs was completed.
- 2017: The walkways on the sector gates were replaced.
- 2022: Contract #W912P622P0013 – Excavated and disposed the 1,000 gallon underground storage tank from the center of the parking area in December 2022.
- 2022: Contract #W912P622P0010 (Cost: $69,750) – Contractor removed a sunken boat that was wrecked and abandoned outside of the chamber for multiple years. A floating plant was used to pull the vessel out of water and

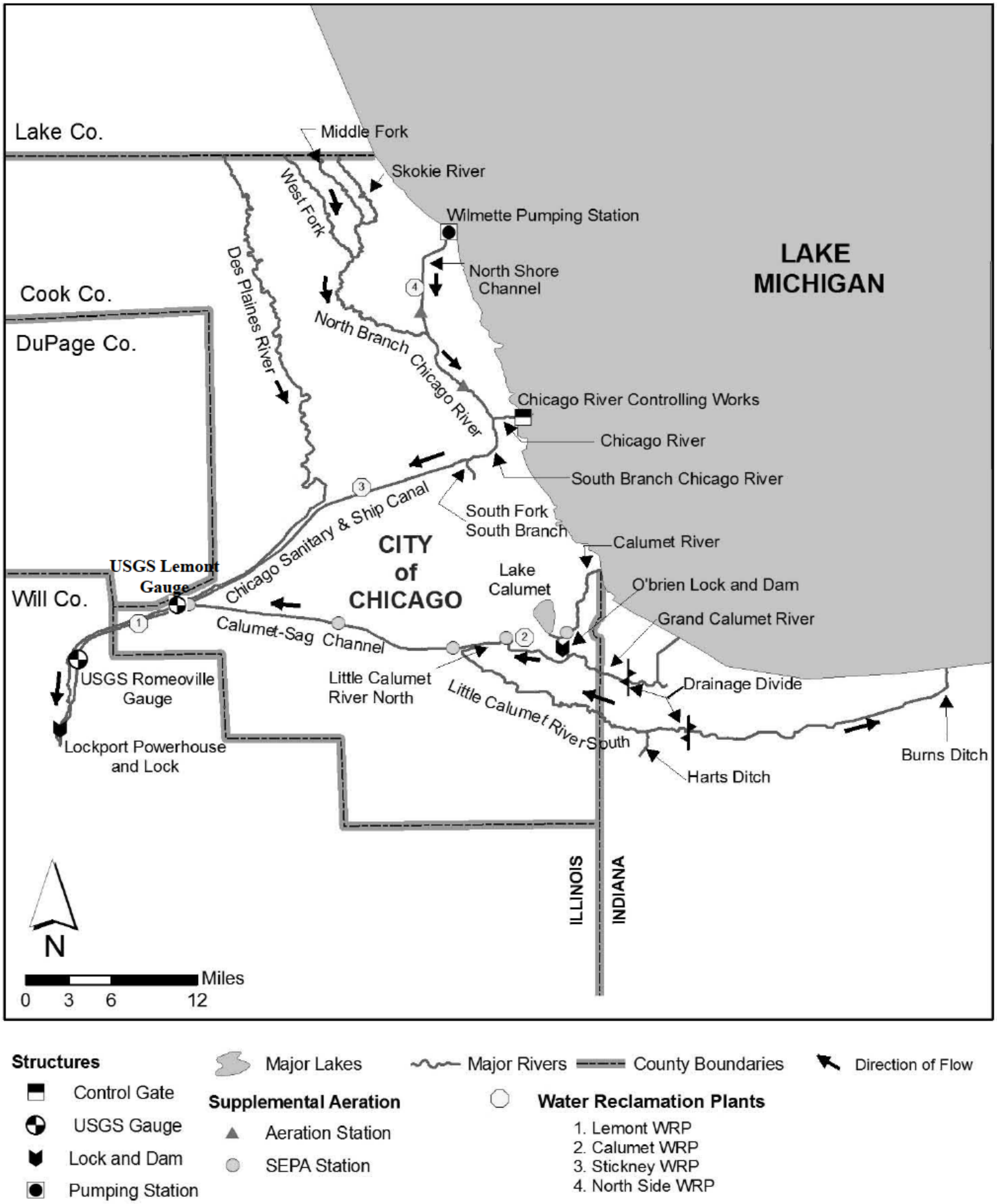
transport it away from the facility. USACE should not have been responsible for this work and the boat owner is expected to reimburse the Government.

- 2022: T-seal on Gate 4 was corrected by MVR divers.
- 2022/2023: Pumps #1 and #2 located in the pipe chase crossing the lock chamber were rehabilitated.
- 2023: Added saw cuts on the bullnose to visually monitor for movement Fall 2023
- 2024: ERDC added strain sensors in January 2024 onto Gate 2 (NW) to monitor vibration, particularly during extreme cold. Initial model was completed in 2023, but instrumentation will provide additional data.
- Ongoing: Design project kicked off in Q2 of FY24 to rehabilitate the east and west access road embankment.
- Ongoing: Funding for major rehabilitation of lock (~$50M) received in 2022. Investigations and design efforts are underway per below:
    - Phase 1A – Completed subsurface investigation including boreholes and test pits along the riverwall, landwall, and guide wall. Borehole locations also included the access road embankments. Also includes dive inspection & testing of sheetpile. Awarded fall 2022 under IDIQ W911XK20D0001, Delivery Order W912P623F0003. Completed in spring 2023.
    - Phase 1B – Complete two design charrettes for the lock. One for the mechanical/electrical features and another for the structural/geotechnical features. Awarded under IDIQ W912QR23D0041, Delivery Order W912P623F0039 in Sept 2023. Expected final report due April 2024.
    - Phase 2 – Plans & Specs to implement the recommended repairs. Will not start until Phase 1A and 1B are complete, but will likely include:
        - Rehabilitation of the land wall, river wall, upper and lower guide wall
        - Replace/rehabilitate sector gate machinery
        - Replace/rehabilitate electrical components
- Ongoing: P&S for filling in 5 distinct scour areas riverside of the lock/controlling works is currently being advertised (W912P6-24-B-0005). Expect work to be completed summer 2024.



576.7, NAVD 88 (mean)
PATH 1 (570.2, NAVD 88)
PATH 2 (565.0, NAVD 88)
PATH 3 (559.6, NAVD 88)
Elevation above North American Vertical Datum of 1988 (NAVD 88), in feet
576.7
575.0
570.0
565.0
560.0
555.0
551.5
0
18
36
54
72
90
108
126
144
162
Distance, in feet
Channel cross section and bathymetry simplified for schematic

Figure 1. Map of the Chicago and Calumet Waterways



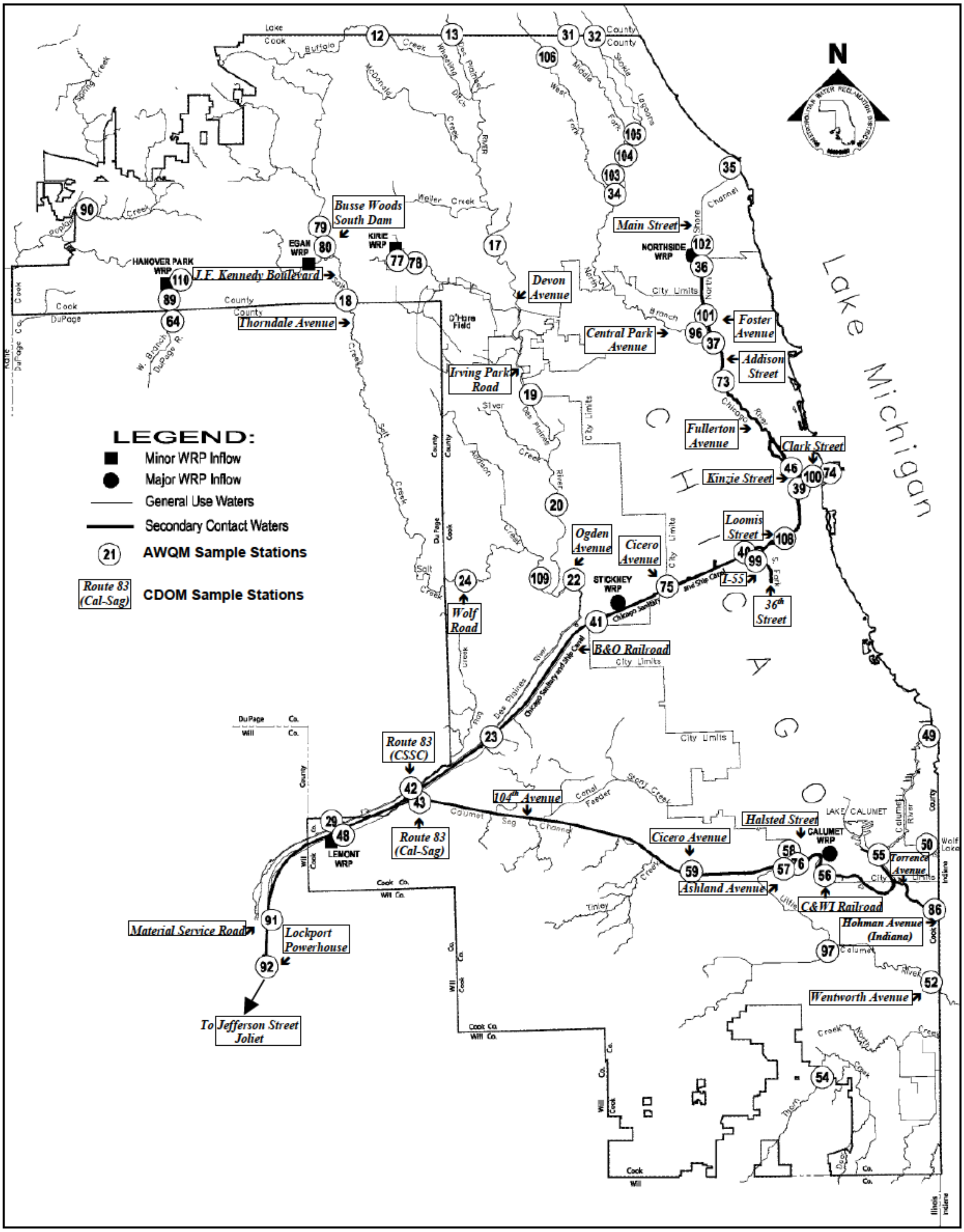
Reversals to Lake Michigan (1985 - Present)
Million Gallons

	Date(s)	O'Brien Lock	CRCW	Wilmette	Total Volume
2023	7/2-7/3		911.8	230.8	1,142.6
2022	None				0.0
2021	None				0.0
2020	5/17-5/18		1731.6	766.7	2,498.3
2020	5/15			50.1	50.1
2019	10/3			54.5	54.5
2018	None				0.0
2017	10/14-10/15		2456.4	289.8	2,746.2
2017	4/29-4/30			19.3	19.3
2016	7/24			34.0	34.0
2015	6/15-6/16		997.5	167.2	1,164.7
2014	6/30-7/1		362.0	163.0	525.0
2013	4/18-4/19	3185.6	6104.7	1429.2	10,719.5
2012	None				0.0
2011	7/23		1716.2	504.3	2,220.5
2011	5/29			107.0	107.0
2010	7/24		5784.6	750.3	6,534.9
2009	6/19			191.6	191.6
2009	3/8			143.1	143.1
2009	2/26-2/27			78.9	78.9
2008	12/27-12/28			460.8	460.8
2008	9/13-9/16	2669.2	5438.2	2941.7	11,049.1
2007	8/23-8/24			224.0	224.0
2006	None				0.0
2005	None				0.0
2004	None				0.0
2003	None				0.0
2002	8/22		1296.4	455.4	1,751.8
2001	10/13			90.7	90.7
2001	8/31			75.3	75.3
2001	8/2		883.1	139.9	1,023.0
2000	None				0.0
1999	6/13			9.7	9.7
1998	None				0.0
1997	8/16-8/17		402.0	157.0	559.0
1997	2/20-2/22	1458.0	1947.0	774.0	4,179.0
1996	7/17-7/18	1032.0	519.0		1,551.0
1995	None				0.0
1994	None				0.0
1993	None				0.0
1992	None				0.0
1991	None				0.0
1990	11/27-11/28	224.0	86.0	154.0	464.0
1990	8/17-8/18			9.5	9.5
1990	5/9-5/10		208.0	289.0	497.0
1989	8/3-8/4			52.0	52.0
1988	None				0.0
1987	8/25-8/26			18.0	18.0
1987	8/13-8/14		986.0	971.0	1,957.0
1986	10/3			53.0	53.0
1985	8/6			58.0	58.0
1985	3/4			153.3	153.3

REVERSALS TO LAKE MICHIGAN

The number of reversals from the Chicago Area Waterway System to Lake Michigan has been reduced with the onset of TARP. There are two types of reversals: gate reversals and lock reversals. The more common is a gate reversal which is characterized by a smaller volume of water released through adjacent gates to the lock. The other type of reversal is a lock reversal, during which the locks are opened to maximize reversal flow. Lock reversals allow a much greater volume of water to flow back to Lake Michigan. They are only necessary in cases of severe storms.

AMBIENT WATER QUALITY MONITORING (AWQM) AND CONTINUOUS DISSOLVED OXYGEN MONITORING (CDOM) SAMPLE STATIONS



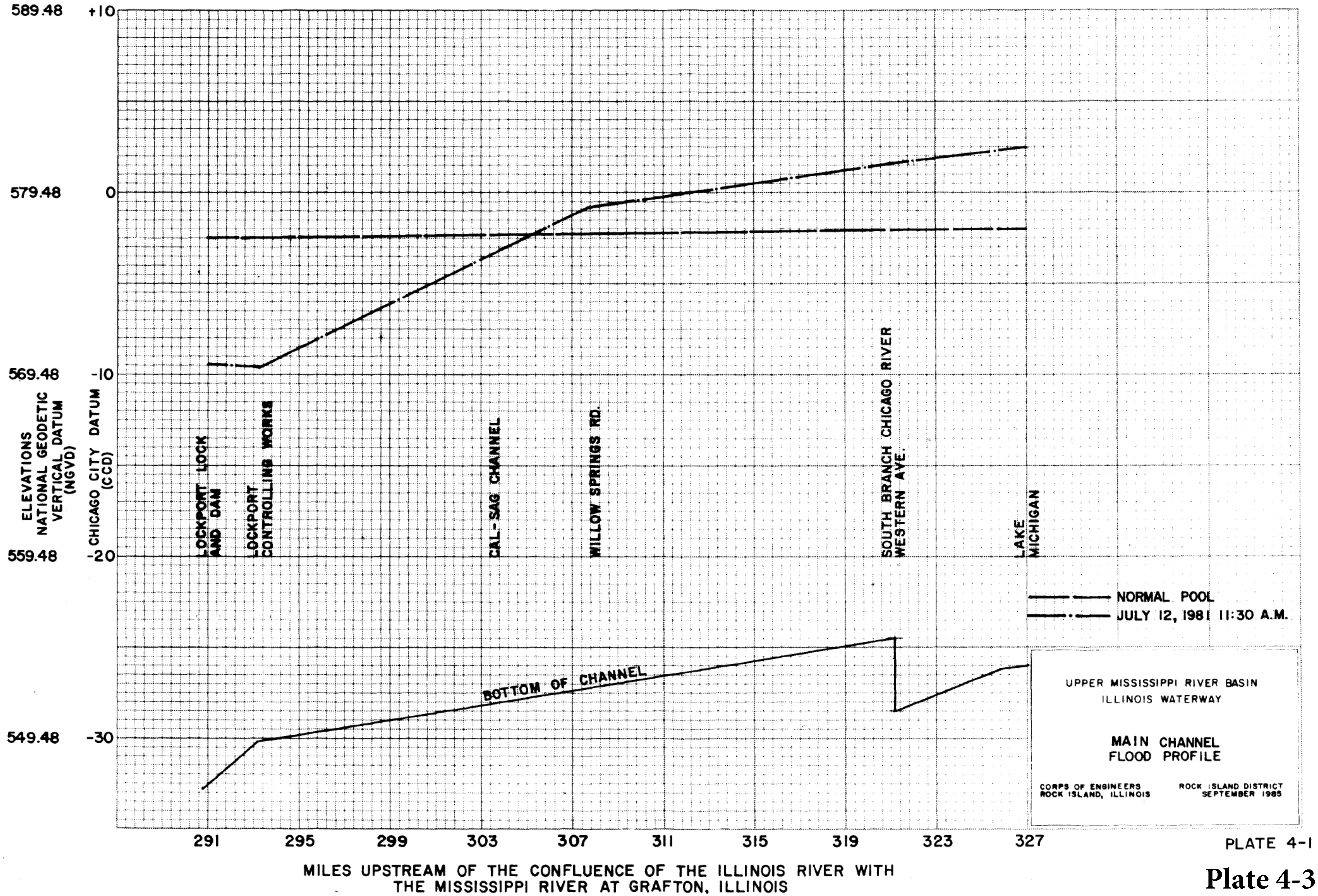

589.48
+10
579.48
0
569.48
-10
559.48
-20
549.48
-30
ELEVATIONS NATIONAL GEODETIC VERTICAL DATUM (NGVD)
CHICAGO CITY DATUM (CCD)
LOCKPORT LOCK AND DAM
LOCKPORT CONTROLLING WORKS
CAL-SAG CHANNEL
WILLOW SPRINGS RD.
SOUTH BRANCH CHICAGO RIVER WESTERN AVE.
LAKE MICHIGAN
NORMAL POOL
JULY 12, 1981 11:30 A.M.
BOTTOM OF CHANNEL
291
295
299
303
307
311
315
319
323
327
MILES UPSTREAM OF THE CONFLUENCE OF THE ILLINOIS RIVER WITH THE MISSISSIPPI RIVER AT GRAFTON, ILLINOIS
UPPER MISSISSIPPI RIVER BASIN
ILLINOIS WATERWAY
MAIN CHANNEL
FLOOD PROFILE
CORPS OF ENGINEERS ROCK ISLAND, ILLINOIS
ROCK ISLAND DISTRICT SEPTEMBER 1985
PLATE 4-1

Plate 4-3

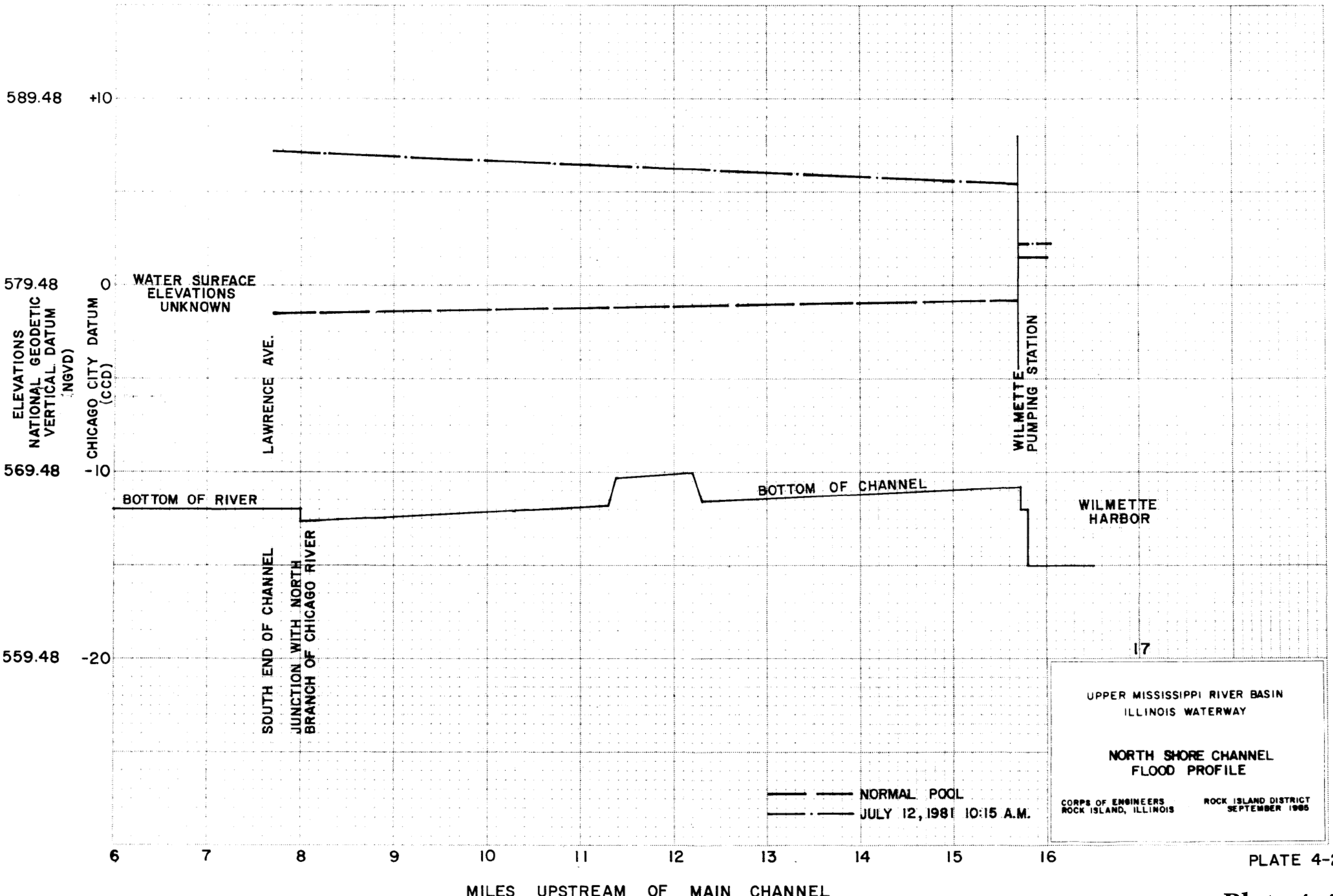
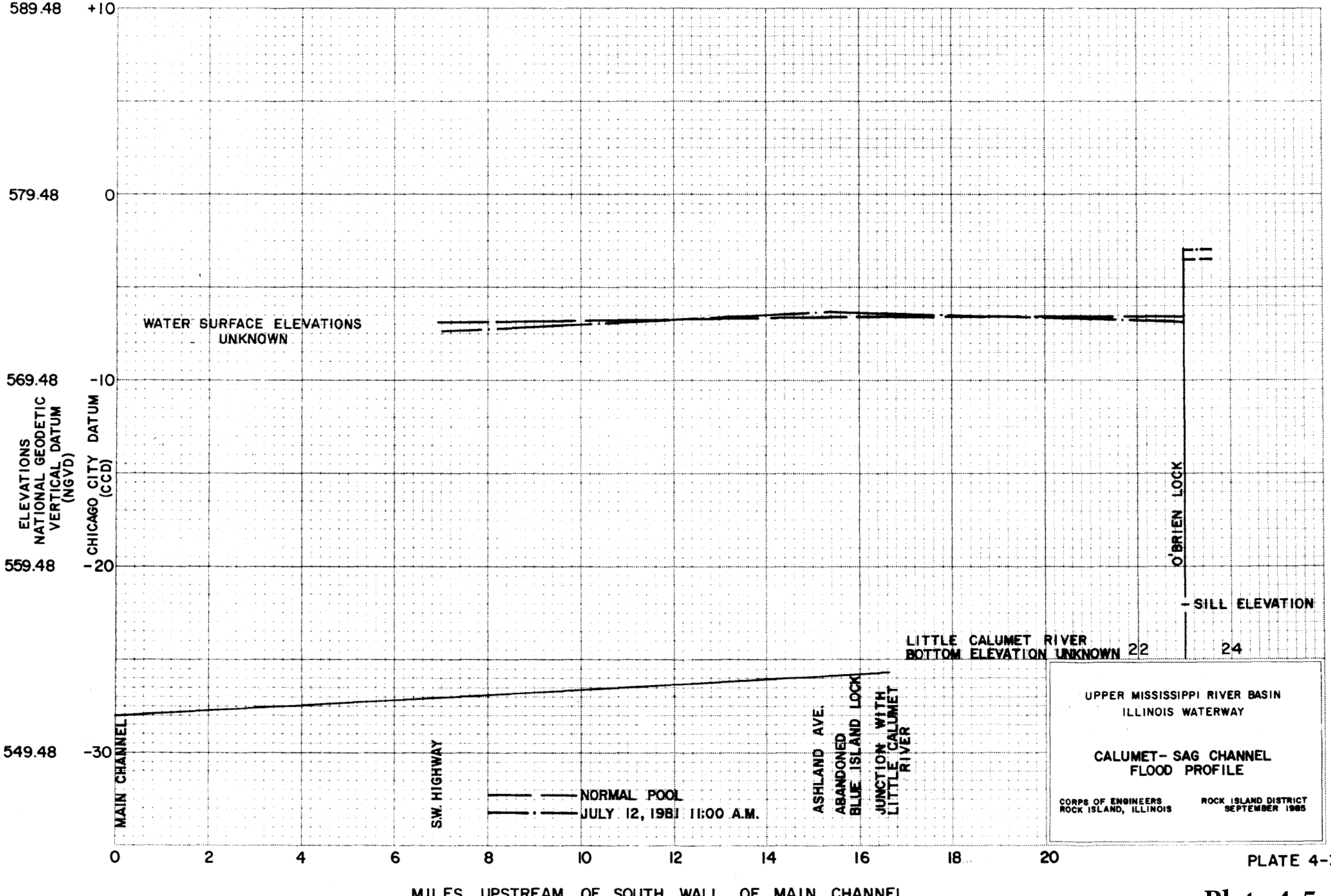


PLATE 4-2

Plate 4-4



589.48
+10
579.48
0
569.48
-10
559.48
-20
549.48
-30
ELEVATIONS NATIONAL GEODETIC VERTICAL DATUM (NGVD)
CHICAGO CITY DATUM (CCD)
WATER SURFACE ELEVATIONS UNKNOWN
O'BRIEN LOCK
SILL ELEVATION
LITTLE CALUMET RIVER BOTTOM ELEVATION UNKNOWN
22
24
MAIN CHANNEL
S.W. HIGHWAY
NORMAL POOL
JULY 12, 1981 11:00 A.M.
ASHLAND AVE.
ABANDONED BLUE ISLAND LOCK
JUNCTION WITH LITTLE CALUMET RIVER
UPPER MISSISSIPPI RIVER BASIN
ILLINOIS WATERWAY
CALUMET- SAG CHANNEL FLOOD PROFILE
CORPS OF ENGINEERS ROCK ISLAND, ILLINOIS
ROCK ISLAND DISTRICT SEPTEMBER 1985
0
2
4
6
8
10
12
14
16
18
20
PLATE 4-3
MILES UPSTREAM OF SOUTH WALL OF MAIN CHANNEL