US Army Corps
of Engineers®
St. Paul District

WATER CONTROL MANUAL

MISSISSIPPI RIVER NINE FOOT CHANNEL
NAVIGATION PROJECT

LOCK AND DAM NO. 3

RED WING, MINNESOTA

APPENDIX 3 OF THE MASTER WATER CONTROL MANUAL

UPDATED AUGUST 2003

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LOCK AND DAM No. 3
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UPPER MISSISSIPPI RIVER BASIN
MISSISSIPPI RIVER – NINE FOOT CHANNEL
NAVIGATION PROJECT

APPENDIX No. 3
of the
MASTER WATER CONTROL MANUAL

U.S. ARMY CORPS OF ENGINEERS
ST. PAUL DISTRICT
ST. PAUL, MINNESOTA

AUGUST 2003

Updated from
Reservoir Regulation Manual, April 1974
Operation of Navigation Pools, February 1943

LOCK AND DAM No. 3

RED WING, MINNESOTA

Aerial View Looking West – October 1995

4 Roller Gates
Project Pool 675.0 feet (1912 Adjustment)

LOCK AND DAM No. 3

RED WING, MINNESOTA

New Lock and Dam No. 3 Control House – November 1991

Lock Chamber and Miter Gates in Foreground

NOTICE TO USERS OF THIS MANUAL

This Water Control Manual complies with the latest US Army Corps of Engineers guidelines regarding management of water control systems and preparation of water control manuals. The St. Paul District prepared the *Preliminary Report on Operation of Navigation Pools* on 16 February 1943. This document provided the operational information for Lock and Dams 1 through 10. It was replaced by a Master Regulation Manual in September 1969. Appendices for each lock and dam were added during the years 1969 through 1974, with Appendix No. 3 being completed in April 1974. This manual is an update of Appendix No. 3. The manual is published in loose-leaf form to facilitate modifications. In the future, only those sections, or parts thereof, requiring changes will be revised and replaced.

EMERGENCY REGULATION ASSISTANCE PROCEDURES

In the event that unusual conditions arise (e.g. gate failure, excessive rainfall), the Lockmaster, Area Lockmaster, and Water Control should be notified as to the extent of the event. During normal water control duty hours (i.e. 0630 to 1730 hrs weekdays and 0630 to 1030 hrs weekends and holidays), contact with water control can be made at 651-290-5624 or 651-290-5474. On weekends and holidays, the Mississippi River Duty Regulator Pager number can be used. If communication with Water Control cannot be established, the following list can be used as a guide for establishing contact.

Water Control Regulation Assistance		
Scott R. Bratten	Primary Mississippi River Regulator scott.r.bratten@usace.army.mil	Duty: 651-290-5624 [redacted]
Duty Regulator	Mississippi River Duty Regulator; Pager and Fax	Pager: 612-660-8053 Fax: 651-290-5841
Dennis D. Holme	Physical Scientist dennis.d.holme@usace.army.mil	Duty: 651-290-5614 [redacted]
Theodore D. Petersen	Water Control Gage Crew theodore.d.Pedersen@usace.army.mil	Duty: 651-290-5253 [redacted]
Ferris W. Chamberlin	Hydraulic Engineer ferris.w.chamberlin@usace.army.mil	Duty: 651-290-5619 [redacted]
Farley R. Haase	Hydrologic Technician farley.r.haase@usace.army.mil	Duty: 651-290-5633 [redacted]
Robert G. Engelstad	Chief, Water Control Section robert.g.engelstad@usace.army.mil	Duty: 651-290-5610 [redacted]
Michael R. Knoff	Chief, Hydraulics & Hydrology Br michael.r.knoff@usace.army.mil	Duty: 651-290-5600 [redacted]
John J. Bailen	Chief, Engineering Division john.j.bailen@usace.army.mil	Duty: 651-290-5303

Lock and Dam No. 3
Red Wing, Minnesota

U.S. Army Corps of Engineers
St. Paul District – August 2003

TABLE OF CONTENTS

EXHIBITS

TABLES

FIGURES

PLATES

PERTINENT DATA

Location: Lock and Dam No. 3 is located on the Mississippi River, 797.0 river miles above the mouth of the Ohio River, 18.3 river miles below Lock and Dam No. 2, and 44.2 river miles above Lock and Dam No. 4. The lock is on the right bank of the river near the town of Red Wing, MN at approximate latitude 44° 36' 36" N and longitude 92° 36' 36" W.

Drainage Area: 45,170 square miles

Datum: MSL - 1912 adjustment

Fixed Height Dam:

Type:	Earth Dike
Length of Earth Dam:	1,400 ft on the Wisconsin side 2,600 ft on the Minnesota side
Crest of Earth Dam:	Elevation 686.0 feet
Top Width of Earth Dam:	20 feet
Max Height of Earth Dam:	14 feet

Spot Dikes:

Number of Spot Dikes:	10 on the Wisconsin side 4 on the Minnesota side
Spot Dike Crest Elevation:	675.0 feet
Top Width of Spot Dikes:	20 feet on the Wisconsin side 10 feet on the Minnesota side
Length of Spot Dikes:	50 – 500 feet on the Wisconsin side 100 – 300 feet on the Minnesota side

Moveable Dam:

Roller Gates	4 Gates - 80 feet by 20 feet
Roller Gate Sill	Elevation 655.0 feet

Lock:

Main Lock Chamber	110 feet by 600 feet
Top of Lock Walls	Elevation 686.0 feet
Top of Upper Gate Sill (Main)	Elevation 658.0 feet
Top of Upper Gate Sill (Auxiliary)	Elevation 656.0 feet
Top of Lower Gate Sill	Elevation 653.0 feet
Lock Floor	Elevation 652.5 feet
Height of Upper Miter Gates (Main)	25.0 feet
Height of Upper Miter Gates (Aux.)	27.0 feet
Height of Lower Miter Gates	30.0 feet

Pool:

Normal (Project) Upper Pool	Elevation 675.0 feet	
Normal (Project) Lower Pool	Elevation 667.0 feet	
Total Pool Area (at Project Pool)	17,950 acres (Mississippi River Segment)	
Primary Control Point	Prescott, WI	Elevation 675.0 ft
Secondary Control Point	Lock & Dam 3	Elevation 674.0 ft

Notes: 1. Roller gates are submergible to 5.0 feet below Normal Pool (675.0 feet).

I – INTRODUCTION

1-01. Authorization for Preparation of this Manual. Pursuant to the instructions from the Chief of Engineers dated 15 May 1942 and 29 August 1942, subject "Operation of Flood Control and Multiple-Purpose Reservoirs", the methods and the technique used in operating the navigation pools on the Mississippi River in the St. Paul District was documented in February 1943. Authority to prepare regulation manuals for the locks and dams was granted by Engineering Regulation (ER) 1110-2-240, *Reservoir Regulation*, 1958. While ER 1110-2-240 has been updated and amended many times since the date of issuance, the document continues to give the Corps of Engineers authority to prepare what became known as "Water Control Manuals" by ER 1110-2-240, *Water Control Management*, 1982. This manual supercedes Lock and Dam No. 3 Regulation Manual dated April 1974 and was prepared in compliance with the guidelines presented in:

a. Engineering Regulation, ER 1110-2-240, *Water Control Management*, 8 October 1982, amended 30 April 1987 and 1 March 1994.
b. Engineering Manual, EM 1110-2-3600, *Management of Water Control Systems*, 30 November 1987.
c. Division Regulation, DIVR 1110-2-240, *Water Control Management, Preparation of Water Control Plans and Manuals*, 1 January 1992.
d. Engineering Regulation, ER 1110-2-8156, *Preparation of Water Control Manuals*, 31 August 1995.

1-02. Purpose and Scope. The purpose of this manual is to provide guidance and instruction for project personnel and to serve as a reference source for others who may be involved with the regulation of this project. The manual is for daily use in Water Control Section activities for most foreseeable conditions and occurrences. The manual covers all water control management activities as they relate to the hydraulic and hydrologic aspects of the project.

1-03. Related Manuals and Reports. The Upper Mississippi River Lock and Dam system was authorized when Congress approved the nine-foot channel on 3 July 1930. A general scheme of operation was developed on 28 March 1935. The following is a list of related Manuals and Reports in chronological order.

a. *Survey of Mississippi River Between Missouri River and Minneapolis*, Letter from The Secretary of War, 72 Congress, 1st Session, House Document No. 137, Part 1 – Report, 9 December 1931.
b. *Report on General Scheme of Operation for the Dams of the 9-Foot Channel Project*, by J. A. Grant, Senior Engineer, War Department, Office of the Chief of Engineers, 28 March 1935.
c. *Preliminary Report on Operation of Navigation Pools,* War Department, US Engineer Office, St. Paul District, St. Paul, Minnesota, 16 February 1943.
d. *Master Regulation Manual for Mississippi River Nine-Foot Channel Navigation Projects*, US Army Corps of Engineers, St. Paul District, September 1969.
e. *Mississippi River Nine-Foot Channel Navigation Project, Reservoir Regulation Manual, Appendix 3, Lock and Dam No. 3, Redwing, Minnesota,* US Army Corps of Engineers, St. Paul District, April 1974.
f. *Creativity, Conflict & Controversy: A History of the St. Paul District, US Army Corps of Engineers,* by Raymond H Merritt, 1979.
g. *Upper Mississippi River, Land Use Allocation Plan*, Master Plan for Public Use Development and Resource Management, Part I and Part II, US Army Corps of Engineers, St. Paul District, September 1983.
h. *Emergency Plan for Lock and Dam 3, Redwing, Minnesota,* US Army Corps of Engineers, St. Paul District, July 1985.
i. *Scour Protection for Locks and Dams 2-10, Upper Mississippi River*, Technical Report HL-87-4, US Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi, April 1987.
j. *Commerce and Conservation on the Upper Mississippi River*, by John O. Anfinson, District Historian, US Army Corps of Engineers, St. Paul District, St. Paul Minnesota, 1990.
k. *Gateways to Commerce*, The US Army Corps of Engineers' 9-Foot Channel Project on the Upper Mississippi River, National Park Service, Rocky Mountain Region, 1992.
l. *Authorized and Operating Purposes of Corps of Engineers Reservoirs*, US Army Corps of Engineers, Washington D. C., July 1992.
m. *Major Rehabilitation Evaluation Report, Lock and Dm 3 Embankments, Mississippi River, Redwing Minnesota*, US Army Corps of Engineers, St. Paul District, February 1994.
n. *Lock and Dam 3 Navigation Safety Study, Mississippi River, Minnesota*, US Army Corps of Engineers, St. Paul District, January 1995.
o. *Channel Maintenance Management Plan,* Upper Mississippi River Navigation System, US Army Corps of Engineers, St. Paul District, 1996.
p. *Channel Maintenance Management Plan, Final Environmental Impact Statement (FEIS),* Lead Agency US Army Corps of Engineers, St. Paul District, Volumes I and II, 6 June 1997.
q. *Record of Decision (ROD) for Final Environmental Impact Statement, Channel Maintenance Management Plan,* Major General Robert B. Flowers, Commander and Division Engineer, Mississippi Valley Division, US Army Corps of Engineers, June 1997.

r. *Zebra Mussel Response Plan*, Environmental Section, St. Paul District, US Army Corps of Engineers, November 1997.

s. *Locks and Dams Sounding Reports, Volume 2*, US Army Corps of Engineers, St. Paul District, 1999.

t. *2001 Annual Report – Water Quality Management Program,* US Army Corps of Engineers, St. Paul District, January 2002.

u. *Locks and Dams Sounding and Diving Analysis,* US Army Corps of Engineers, St. Paul District, 2002.

1-04. Project Owner. The United States Government is the owner of Lock and Dam No. 3. The US Army Corps of Engineers, St. Paul District, St. Paul, Minnesota, is responsible for operation and regulation of Lock and Dam No. 3.

1-05. Operating Agency. Lock and Dam No. 3 is regulated, operated, and maintained by the US Army Corps of Engineers, St. Paul District. Regulation is the responsibility of Engineering Division, while operation and maintenance is the responsibility of Construction and Operations (Con-Ops) Division. The following chart shows the command structure for Lock and Dam No. 3.

St. Paul District Office
← ← ← **District Engineer** → → →

↓	↓
Chief Engineering Division	**Chief Con-Ops Division**
↓	↓
Chief H&H Branch	**Chief Lock & Dam Project Office**
↓	↓
Chief Water Control Section	**Area Lockmaster**
↓	↓
Water Control Manager	**Lockmaster**
651-290-5624 → → → → → →	651-388-5794
fax 651-290-5841	fax 651-388-6627

The project is attended 24 hours a day, every day of the year. The Chief, Con-Ops Division and the Chief, Engineering Division are located in the St. Paul District Office, whereas the Lock and Dam Project Office is located in Fountain City, Wisconsin and the Area Lockmaster is stationed at Lock and Dam No. 2.

1-06. Regulating Agency. Regulation of Lock and Dam No. 3 is under the supervision of the Water Control Section as by the above command structure.

II – DESCRIPTION OF PROJECT

2-01. Location. Lock and Dam No. 3 is located on the Mississippi River, 797.0 river miles above the mouth of the Ohio River, 18.3 river miles below Lock and Dam No. 2, and 44.2 river miles above Lock and Dam No. 4. The lock is on the right bank of the river about six river miles above the city of Red Wing, Minnesota at approximate latitude 44° 36’ 36” N and longitude 92° 36’ 36” W. The project is bordered by Pierce County on the Wisconsin side and Goodhue County on the Minnesota side. The project location is shown on **Plate 2-1**. Mailing address is:

Lock and Dam No. 3
4330 Lock and Dam Road
Welch, Minnesota 55089-9644

2-02. Purpose. Lock and Dam No. 3 is a unit of the Inland Waterway Navigation System of the Upper Mississippi River Basin. The system includes 29 locks and dams, which provide a “stairway of water” from Minneapolis, Minnesota to St. Louis, Missouri. The primary purpose of the dams is to maintain a depth of nine feet for navigation. The authorized purposes for Lock and Dam No. 3 are navigation under the River and Harbors Act of 1930 (PL 71-250) and recreation under the Flood Control Act of 1944 (PL 78-534). Access and facilities are provided for recreation but water is not controlled for that purpose.

2-03. Physical Components. Lock and Dam No. 3 consists of a main and uncompleted auxiliary lock, a movable dam section, an earthen dike, and four spot dikes on the Minnesota side and ten spot dikes on the Wisconsin side. The Mississippi River is divided into two channels by an island at the project site with the locks located in the southern channel and the movable dam section located in the northern channel (**Figure 2-1**). The locks and moveable dam are supported on timber piling driven into sand and gravel. The moveable dam, the locks, the left embankment, and all the spot dikes on the Wisconsin side have sheet pile cutoff walls.

Figure 2-1. Lock and Dam No. 3 (Looking Downstream)

a. Lock. Lock and Dam No. 3 has a main and an uncompleted auxiliary lock (**Plate 2-1**). The upper and lower miter gates of the main lock have a height of 25.0 feet and 30.0 feet respectively. The respective sill elevations are 658.0 feet and 653.0 feet (1912 adjustment). A walkway is located atop the miter gates. It extends three feet above the top of miter gates (elevation 683.0 feet) to meet the top of lock walls (elevation 686.0 feet). While the main lock is fully functional, the auxiliary lock consists of only an upper gate bay. The miter gates on the auxiliary lock are 27 feet high with a sill elevation of 656.0 feet. The gates of the auxiliary lock have no machinery and therefore are inoperable.

The main lock is 110 feet wide with a clear length of 600 feet. Filling and emptying of the lock chamber is controlled by tainter valves; two at the upstream (upper) end of the lock and two at the downstream (lower) end. During the filling or emptying process, the miter gates are closed thus sealing the lock chamber. For a filling operation, the upper tainter valves are opened allowing flow to enter the culverts (**Plate 2-2**, Section A-A). Flow then enters the lock chamber through ports along the lock wall (Section X-X) and the water level in the lock chamber rises until it equals the pool elevation. The upper tainter valves are then closed and the lower tainter valves are opened thus emptying the lock chamber. Under normal conditions, filling and emptying times are about ten minutes.

Periodically, the lock chamber is flushed of sediment and debris. This is accomplished at the end of an emptying cycle. The upper miter gates and lower tainter valves are in the closed position, the lower miter gates are opened in the recessed position, and the upper tainter valves are operated to provide the flushing action.

Guide walls are located upstream and downstream of the lock to provide a landing for down bound and up bound tows (**Plate 2-1**). The upper guide wall extends 519 feet upstream and the lower guide wall extends 504 feet downstream.

b. Moveable Dam. The moveable dam section extends from the island to the left bank of the main channel (see **Plate 2-1**) and consists of four roller gates, 80-feet wide by 20-feet high (**Figure 2-1**). The gate sill elevations are 655.0 feet (1912 adjustment). The end sill elevations are at elevation 652.5 feet. The roller gates can be submerged down to elevation 670.0 feet, which is five feet below normal pool.

Each roller gate is equipped with an individual electrically operated hoist enclosed in an operating house located on the pier. The roller gates are driven from one end only. The travel rate of the gate is approximately 0.75 feet per minute. A position indicator (**Figure 2-2**), marked in increments of 0.1 feet, is attached to the hoist mechanism.

Figure 2-2. Roller Gate Position Indicator

An alternate position indicator (**Figure 2-3**), showing the gate opening and top of roller gate drum elevation in increments of 0.5 ft, is attached to a shaft with a gear driven by the hoist mechanism.

Figure 2-3. Alternate Roller Gate Position Indicator

Should the need arise to block flow through a roller gate bay, there are five bulkheads stored on site. They measure 4 feet-2 inches by 85 feet-4 inches. The sill elevation is 655.0 feet; therefore, with five bulkheads in place, the top of the bulkheads would be at elevation 675.83 feet (i.e. 675 feet-10 inches).

A service bridge, at elevation 704.5 feet, spans the entire length of the moveable dam and storage yard and provides for the operation of the crane. The 40-foot boom crane, with 20-ton capacity, was replaced in 1981. The new crane has a boom length of 60 feet and a capacity of 20 tons.

c. **Channel Protection.** Immediately upstream and downstream of the moveable dam, the channel is protected concrete followed by stone protection. Section B-B of **Plate 2-2** shows the original derrick stone protection. Over the years, scour upstream and downstream of the dam caused some unraveling of the derrick stone. In the 1983, riprap protection was extended upstream and downstream in the form of capstone and rockfill. **Plate 2-3** shows two transects of the added protection. The following gives a description of the riprap protection near the roller gates, lock, auxiliary lock, and storage yard.

(1) Roller Gates. Downstream protection originally consisted of derrick stone 3-feet thick with a top of rock elevation of 650.5 feet (1912 adjustment) placed on a 2-foot thick lumber mat. The derrick stone extended 41.5 feet downstream of the end sill. Upstream protection consisted of a 12-foot wide, 3-foot thick section of derrick stone with a top elevation of 654.0 feet.

The scour holes that formed within the deteriorating original derrick stone were filled in 1983. Downstream of the roller gates, capstone was placed in either a 3.5-foot thick layer or a 10-foot thick wedge, depending on location, with a top of rock elevation of 650.5 feet, corresponding to the top of the original derrick stone. Beneath and downstream of the capstone, a minimum 2.5-foot thick rockfill section extended downstream of the roller gate end sill at a 1V:3H slope to where it intersected high ground or to 125 feet, whichever was greater.

Following a barge incident in 1993 in which a barge blocked flow through the southern gates of the moveable dam, six to eight barge loads of rock were placed downstream of the dam on the north side. Upstream of the roller gates, a horizontal 3.5-foot thick capstone section, underlain by a rockfill section a minimum of 2.5-feet thick, was placed with a top of rock elevation of 654.0 feet. The capstone extended 45 feet upstream of the roller gate piers. The rockfill section went form the top of the existing ground line up to the base of the capstone and resulted in a section exceeding 8 feet in places. Soundings were taken approximately two months after the barge incident. The high velocity flow through the northern gates combined with the flow around the north side of the dam caused large-scale scour downstream of the dam along the northern side of the channel. Differences between the 1992 and 1993 channel profiles showed displacement of up to 30 feet of material on the far northern side of the channel. A 48-inch thick rock section was placed downstream of the northern side of the movable dam in the summer of 1995. Soundings taken in 1998 showed the scour hole to be centered about 350 feet downstream of pier 3 with a minimum elevation near 590 feet.

(2) Lock and Guidewalls. The original scour protection downstream of the lock and along the guidewall consisted of a 3-foot thick section of derrick stone underlain by 12-inch layer of riprap. A 10.5-foot wide section was placed along the downstream side of the main and auxiliary lock sills, on the riverward side of the riverward wall of the main lock chamber, and along the guide wall for a distance of 100 feet. Upstream scour protection consisted of a 13.5-foot wide section placed at the upstream end of the riverward and intermediate lock walls and a 10.5-foot wide section along the upper guide wall for a distance of 66 feet. No rock protection was provided at the end of the concrete sills at the upstream end of the main and auxiliary lock chambers.

Additional scour protection was placed along the upper and lower guide walls in 1983. A 2.5-foot thick section of graded riprap was placed along the upper and lower guide walls. The section extended out horizontally from the upper guide wall for a distance of 20 feet at elevation 655.5 feet and then sloped down to meet the existing ground on a 1V:5H slope. The downstream guide wall protection is similar except that the top of rock elevation is at 651.5 feet.

(3) Storage Yard. Original scour protection downstream of the storage yard consisted of 12-inch riprap placed on a 1V:2H slope. Upstream protection consisted of 2-foot derrick stone over 6-inches of gravel placed on a 1V:2H slope for a maximum distance of about 60 feet down to elevation 656.0 feet then horizontally for a distance of 10 feet.

d. Earthen Dams. On the Minnesota side of the river, an earthen dam and access road extends from the end of the land wall of the main lock 2,600 feet southwestward to high ground near the railroad embankment. Side slopes are 1V:5.5H on the pool side and 1V:3H on the landward side. It has a crest elevation of 686.0 feet (1912 adjustment) and a 20-foot top width (**Plate 2-2**). Scour protection is provided by a 12-inch layer of riprap placed on top of a 6-inch gravel bedding. On the upstream side riprap extends from the toe to the crest. On the downstream side, riprap extends from the toe to elevation 669.0 feet (i.e. two feet above normal lower pool level). Section C-C of **Plate 2-2** shows the access road surface to be comprised of clay. This has been replaced with a bituminous road mixture. On the Wisconsin side of the river an earthen dam extends from the movable dam due north for a distance of about 275 feet with 1V:3H side slopes upstream and downstream and a crest width 30.5 feet. At this point, the embankment turns northwest for a distance of about 125 feet where it ties into Spot Dike A of the Spot Dike System (see **Figures 2-5** and **2-8**). This portion of the embankment has a crest elevation of 686.0 feet and a top width of 20 feet. The pool side slope is 1V:3H and the landward side slope is 1V:8H. Scour protection consists a 12-inch layer of riprap placed over 6 inches of gravel bedding. It extends from the toe of the pool side slope to the crest and on the landward side, it extends from the toe to elevation 682.0 feet. Seepage is controlled by sheet piling driven along the total length of the embankment (400 feet).

e. Spot Dikes. Multiple spot dikes were built on both sides of the Mississippi River by the Corps of Engineers to prevent loss of pool through sloughs and other low-lying areas. On the Minnesota side, the Vermillion Slough Dike is located about 16 miles upstream of the dam. Truedale Slough Dike, Carter Slough Dike, and Spot Dike K are located about 11 miles upstream of the dam.

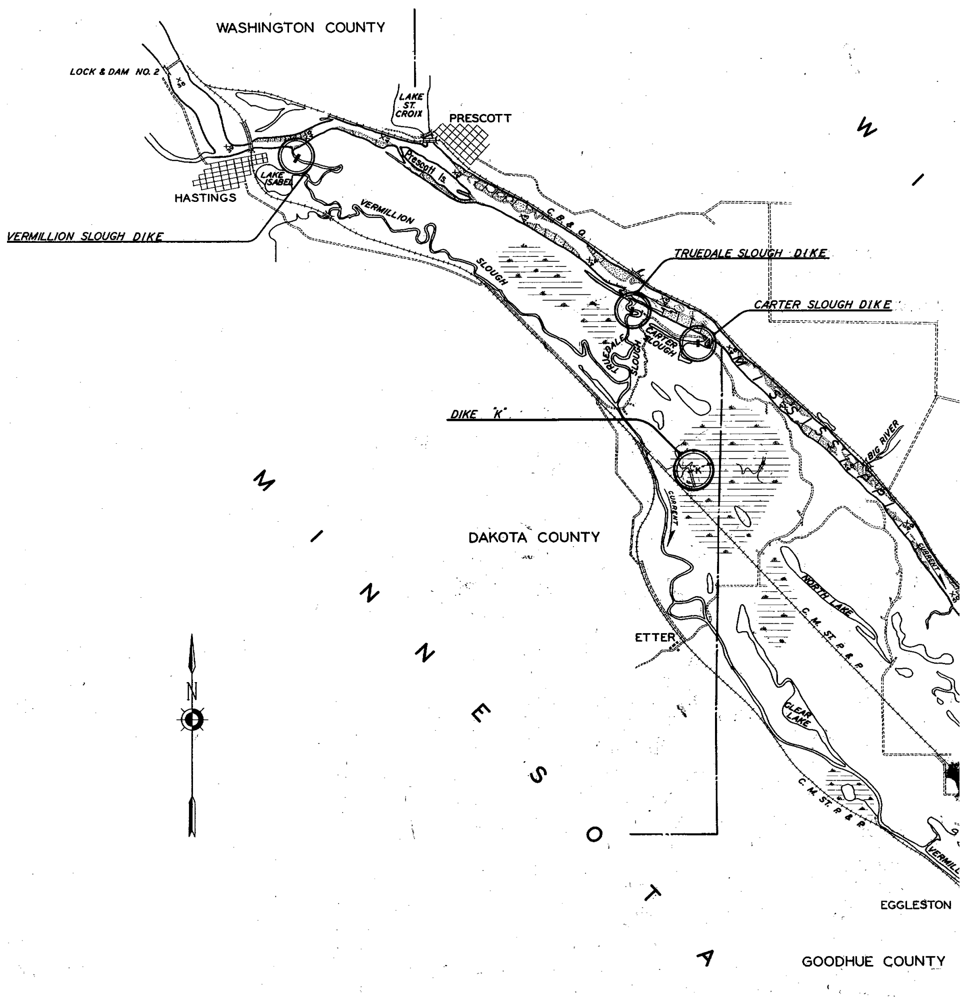

Figure 2-4. Minnesota Spot Dikes.

These dikes have a crest elevation of 675.0 feet and a top width of 10 feet. They vary in length from 100 to 300 feet. The spot dikes on the Minnesota side allow flow from the Mississippi River to overtop into Vermillion Slough, which enters the main channel downstream of Lock and Dam No. 3.

On the Wisconsin side, Spot Dike A begins at the left dam embankment and extends upstream 1,000 feet. The crest elevation starts at 686.0 feet at the embankment and slopes downward to elevation 676.0 feet where it ties into higher ground. Seepage is controlled over its entire length by steel sheet pile.

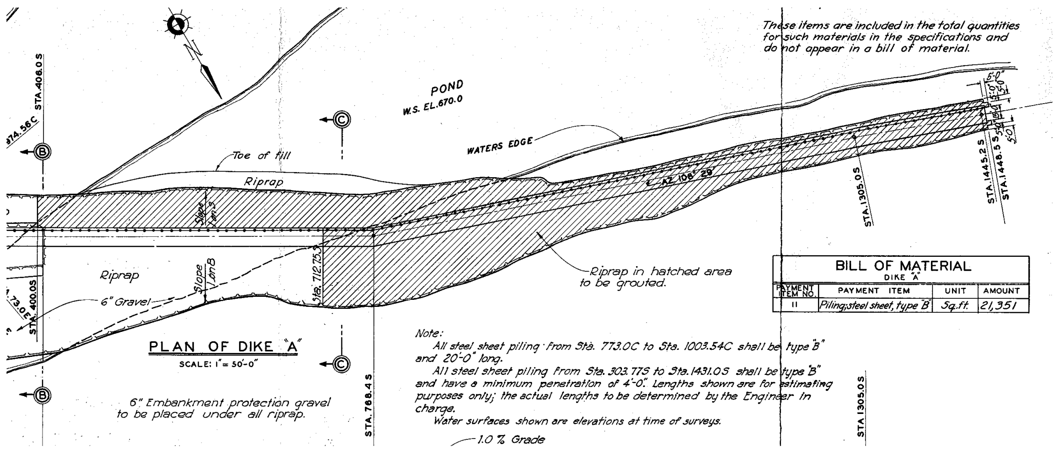

Figure 2-5. Plan View of Spot Dike A.

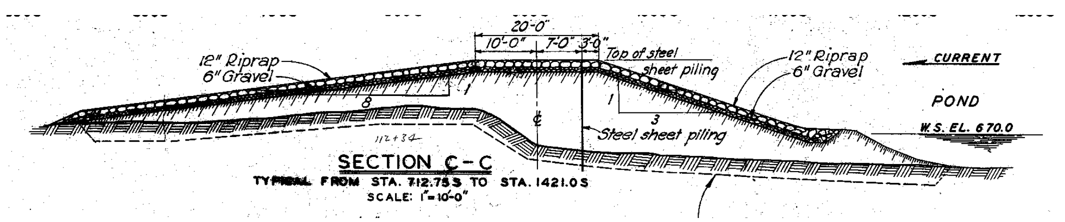

Figure 2-6. Spot Dike A – Cross Section C-C.

Spot Dikes B through J are spread out along the left riverbank for a distance of about two miles. In general these dikes have a top width of 20 feet and a crest elevation of 675.0 feet and vary in length from 50 to 500 feet. **Figure 2-7** shows the location of these spot dikes.

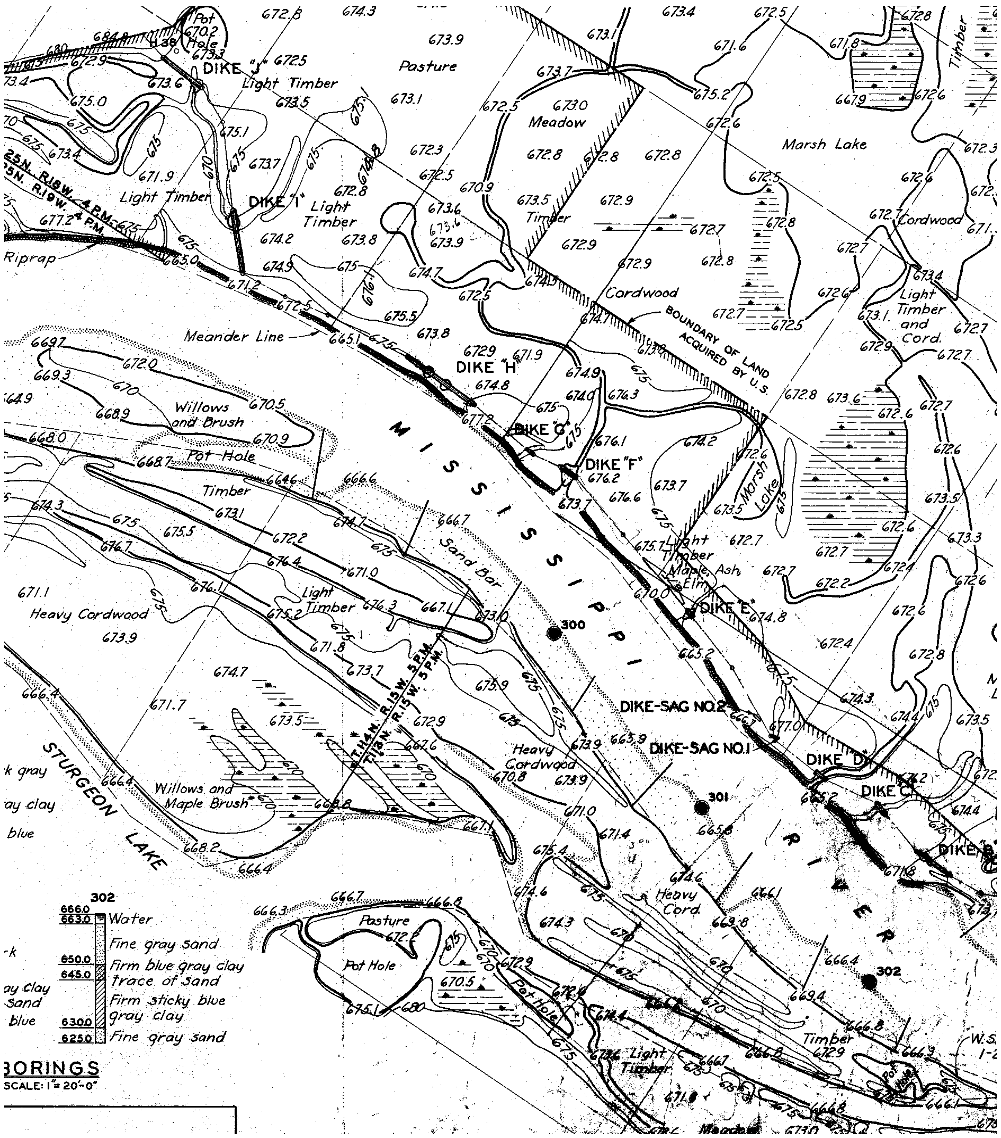

Figure 2-7. Wisconsin Spot Dikes B through J.

The Spot Dikes on the Wisconsin side allow flow to overtop into a series of lakes separated by privately owned dikes, which divide the head at the dam into multiple steps. After flow crosses the Spot Dike System, it enters Marsh Lake. Water then crosses what is know as the Intermediate Dike and enters Gantenbein Lake as shown in **Figure 2-8**. From there flow overtops the Lower Dike at Gantenbein Lake and enters the main channel of the Mississippi River. While the Spot Dikes are federal owned, the Intermediate and Lower Dikes are privately owned by the Diamond Bluff Associates.

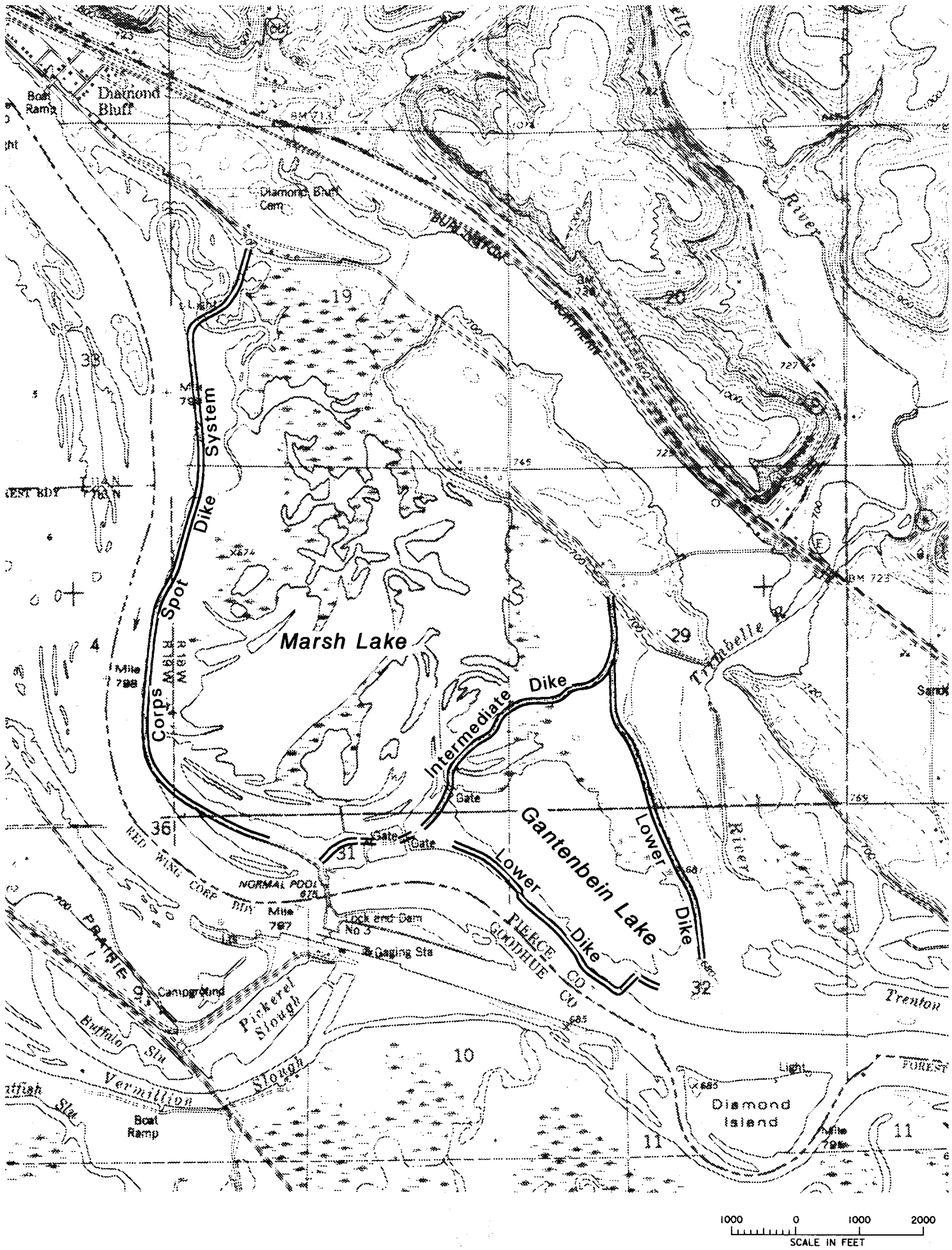

Figure 2-8. Spot Dikes, Intermediate Dike, and Lower Dikes.

2-04. Related Control Facilities. There are no related control facilities in Pool No. 3; however, Xcel Energy owns and operates the Prairie Island Nuclear Power Plant on the Mississippi River and Allen King Power Plant on the St. Croix River. The power plants extract water from the pool created by Lock and Dam No. 3 for use as a coolant. If the pool elevation drops below 671.0 feet, the power plants are forced to shut down.

2-05. Real Estate Acquisition. In Pool No. 3, the US Government holds in fee 5,672.63 acres. Of this total, 5,604.73 acres are under the jurisdiction of the Corps of Engineers and the balance of 67.90 acres is under the jurisdiction of the Department of Interior. Of the Corps of Engineers land, the approximate distribution is as follows; 3,740 acres was assigned to the Minnesota Department of Natural Resources (MDNR) for use as a wildlife management area, 1,350 acres was assigned to the Bureau of Indian Affairs (BIA) for use of the Prairie Island Indian Reservation, 130 acres was leased to the city of Hastings, Minnesota for recreational uses, 21 acres is being used as a barge fleeting area in the vicinity of Prescott Island, and 364 acres remain under the management of the Corps of Engineers. **Table 2-1** shows a break down, by county, of Corps of Engineers land held in fee and flowage easement.

Table 2-1
Land Held in Fee and Flowage Easement for Pool No. 3 (acres)

State	Minnesota		Wisconsin	
County	Goodhue	Dakota	Pierce	Totals
Fee	4,953.83	353.89	297.01	5,604.73
Easement	52.64	10.26	205.40	268.30

In addition to these lands, the Corps also periodically enters into a written agreement with the Diamond Bluff Associates for an easement to maintain and repair the Intermediate and Lower Dikes (**Figure 2-8**) when there is an emergency. The present agreement cost $16,000 and expires 5 February 2007.

2-06. Public Facilities. Public facilities at the project site include restrooms and a viewing platform. In addition to the facilities at the lock and dam, there are numerous other facilities located throughout the pool. **Table 2-2** shows a list of the recreational facilities located in Pool No. 3.

Table 2-2
Recreation Facilities on the Mississippi River in Pool No. 3

River Mile	Name	Manager	Fee	Slips	Parking	Camp Sites	Toilets	Picnic Tables
814.3 R	Hastings Public Landing	MDNR & Hastings	No		80	No	Yes	Yes
814.3 L	Hubs Bait	Private	Yes	22	10	No	Yes	No
813.8 L	Kings Cove Marina	Private	Yes	400	100	No	Yes	No
813.3 R	Hastings Marine Inc.	Private	Yes	110	50	No	Yes	No
811.4 L	Leo's Landing	Private	No	28	10	No	Yes	No
811.3 L	Point St. Croix Marina	Private	No	70	15	No	Yes	No
811.2 L	Jacques Public Landing	Prescott	Yes		50	No	Yes	No
811.0 L	Miss – Croix Yacht Harbor	Private	No	134	30	No	No	No
804.5 R	North Lake Access	MDNR	No		10	No	No	No
800.0 R	Treasure Island Casino	Prairie Island Tribe	No	137	50	Yes	Yes	No
800.0 L	Diamond Bluff	Diamond Bluff	No		6	No	No	No
799.0 R	Sturgeon Lake Landing	MDNR	No		10	No	No	No

Table 2-3
Recreation Facilities on the St. Croix River in Pool No. 3

River Mile	Name	Manager	Fee	Slips	Parking	Camp Sites	Toilets	Picnic Tables
24.8 R	St Croix Boomsite	MN DNR	No		20	No	Yes	Yes
24.5 R	Wolf Marine	Private	No	236	100	No	Yes	No
24.3 R	Rumpts Dutch Harbor	Private	Yes	70	20	No	No	No
23.5 R	Stillwater Yacht Club	Private	Yes	300	100	No	Yes	No
23.2 R	Stillwater Municipal Dock	Stillwater	No		20	No	No	No
22.2 R	Sunnyside Marina	Private	Yes	196	90	No	Yes	No
20.2 R	Bayport 4th Ave. Ramp	Bayport	No		20	No	Yes	Yes
19.7 R	Beach House Marina	Private	Yes	15	20	No	No	No
19.6 R	Walts Boat Docks	Private	No	67	20	No	Yes	No
19.0 R	Bayport Marina	Private	No	236	50	No	Yes	No
16.6 L	Hudson Lakefront Park	Hudson	Yes		40	No	Yes	Yes
16.3 L	St. Croix Marina	Private	Yes	298	100	No	Yes	No
15.9 R	Beanies Resort	Private	Yes	10	30	No	Yes	No
10.1 L	Glenmont Road Ramp	Try Township	No		5	No	No	No
11.5 R	Afton Marina	Private	No	184	100	No	No	No
11.3 R	Windmill Marina	Private	Yes	168	100	No	No	No
8.5 R	Afton State Park	MN DNR	No			No	Yes	Yes
6.5 L	Kinnickinnic State Park	WI DNR	No			Yes	Yes	Yes
3.8 R	St. Croix Bluffs Reg Park	Washington Cty	Yes		50	Yes	Yes	Yes
1.3 R	Point Douglas Marina	Private	Yes	24	15	No	Yes	Yes

III – HISTORY OF PROJECT

3-01. Authorization. The Lock and Dam No. 3 project was authorized on 3 July 1930 when the 71st Congress, second session, passed an act that modified the existing six-foot channel project in accordance with the plan for a comprehensive project to procure a channel of nine-foot depth, submitted in House Document No. 290. The nine-foot channel was to be achieved through the construction of a system of locks and dams, supplemented by dredging.

3-02. Planning and Design. The site for Lock and Dam No. 3 was originally chosen to be 21.6 miles below Lock and Dam No. 2 and was considered to be one of the best sites for a lock above Lake Pepin. Its location above the town of Red Wing, Minnesota would obviate possible flowage damage to the town. Also, the dike for the dam would have diverted the Cannon River into Pool No. 3, thus reducing dredging requirements if otherwise allowed to flow into the upper reaches of Pool No. 4. A good six-foot channel was available if dredging continued, so the site was given a relatively low priority in the nine-foot channel project. In an effort to prevent inundation of politically sensitive lands, the final location of Lock and Dam No. 3 was moved 3.3 miles upstream from its originally planned location to a location 18.3 miles downstream of Lock and Dam No. 2 at the outlet of Vermillion Slough and about 6 miles upstream of Red Wing, Minnesota.

The lock and dam system is necessary to provide a nine-foot channel during low to moderate flows. The dam is operated to accommodate river flow conditions. In normal operation, all gates are partially open to allow water through. As the river flow increases or decreases, the gate openings are increased or decreased accordingly. If there were no flow in the pool, the pool would be level throughout its entire length. This is the “project pool” level that ensures a nine-foot channel depth. When there is flow, there is a slope to the water surface. Typically the water surface is maintained at project pool elevation at a predetermined point upstream of the dam, known as the “primary control point”. Its location is near the point of intersection of the “project pool” (flat pool level) and the “ordinary high water" profile. The ordinary high water mark can be considered "the point up to which the presence and action of the water is so continuous as to destroy the value of the land for agricultural purposes by preventing the growth of vegetation, constituting what may be termed any ordinary agricultural crop". The government of the United States holds an easement to use the riparian lands up to the ordinary high water in the public interest. Therefore, land inundated by the lock and dam above the ordinary high water profile was purchased in fee. This land lies between the primary control point and the dam.

The primary control point for Lock and Dam No. 3 was located at Prescott, Wisconsin with an elevation of 675.0 feet (1912 adjustment). The project pool elevation is maintained at the primary control point until discharge at the dam is sufficient to allow for a drawdown at the dam. As originally designed, maximum drawdown was established at 2.0 feet below project pool, or elevation 673.0 feet. Maximum drawdown was reduced to 1.0 foot or elevation 674.0 feet in 1971 (see **Paragraph 3-05.b**). As discharge increases, the gates are raised to maintain the maximum drawdown. As discharge continues to increase, eventually all the gates are raised above the water surface and open river conditions exist. When this condition occurs, the dam is said to be "out of control".

The total number of gates required at each site is based on the allowable swellhead at extreme high water. For Lock and Dam No. 3 the swellhead is limited to less than one foot. The project design flood for Lock and Dam No. 3 was the flood of 1881. The design high water was elevation 682.2 feet with a flow rate of 134,000 cfs. The swellhead limitation required that the available floodway area be utilized to the greatest possible degree. As a consequence gate sills were set to the lowest possible elevation. The valley at the lock and dam site is approximately 3 miles wide between high sandstone bluffs. The river is about 600 feet wide at normal flows but at extreme high water, the width can reach 2.5 miles. The limited width left room for only four roller gates to cross the main channel. The gates do not allow sufficient flow to meet the swellhead limitation, therefore when flows exceed 36,000 cfs, a series of spot dikes on the Wisconsin side of the channel are overtopped and flows are routed around the lock and dam.

A single primary and uncompleted secondary lock provides navigation. The lock system was constructed across the opening of Vermillion Slough. The upstream approach channel was excavated from the native soil along the right bank of the Mississippi River. The downstream approach channel was excavated from the right bank of a previously cut-off secondary channel at the confluence with Vermillion Slough. Vermillion Slough was rerouted further downstream via a cutoff channel.

3-03. Construction. Exploratory borings revealed that the stratum of silt, sand and plastic clay encountered in the lock area during its construction also extended beneath the proposed site of the dam. Since it was highly improbable that the piling driven into this material would afford adequate resistance to horizontal loads, it was decided that this material should be removed and replaced with clean river sand. Approximately 200,000 cubic yards of material were removed and replaced by 130,000 cubic yards of sand. Construction of the lock began on 6 August 1935 and was completed on 13 April 1937. Construction of the dam began on 2 February 1937 and was completed on 30 March 1938. The total cost of Lock and Dam No. 3 was approximately $4,660,000.

3-04. Related Projects. Lock and Dam No. 3 is one part of the 29 locks and dams on the Mississippi River necessary to maintain the nine-foot navigation channel between Minneapolis, Minnesota and St. Louis, Missouri. Thirteen of the 29 locks and dams are located in the St. Paul District. These include Upper and Lower St. Anthony Falls, as well as Lock and Dam Numbers 1 through 10.

3-05. Modifications to Regulation.

a. 1948 Modification. The nine-foot channel depth was only important during the navigation season. Therefore, the pool could be drawn down far below project pool over the winter months whenever it was considered necessary. On 19 June 1948, an amendment was made to the act of Congress dated 10 March 1934, entitled “An act to promote the conservation of wildlife, fish and game, and for other purposes”. The amendment was Public Law 697 and it prevented drawdown of the pools on the Mississippi River between Rock Island, Illinois and Minneapolis, Minnesota during the non-navigation season. The law is known as the “Anti-Drawdown Law”. The law states that the “…dam structures shall generally operate and maintain pool levels as though navigation was carried on throughout the year.”

b. 1971 Modification. In an attempt to reduce the frequency of dredging, the navigation channel was often over dredged. This practice stopped in 1970. Therefore, drawdown at the dam was reduced from 2.0 feet to 1.0 foot, or elevation 674.0 feet (1912 adjustment). This remains today as the secondary control elevation.

c. 1973 Modification. Discharge through the dam was reevaluated in 1973 by the USGS. This resulted in a slight change in the discharge per foot of opening on the roller gates. Therefore, the Gate Regulation Schedule was revised.

d. 1983 Modification. In 1981, the Waterways Experiment Station began a study of the scour protection upstream and downstream of the Mississippi River dams and published their results in *Scour Protection for Locks and Dams 2-10, Upper Mississippi River*, Technical Report HL-87-4, April 1987. Since 1952, hydrographic surveys indicated that scour had occurred upstream and downstream of the dam. The purpose of the study was to develop a riprap design that would stabilize the existing conditions. Based on the preliminary results of the study, additional riprap protection was placed upstream and downstream of the dam in 1983. Because there may occasionally be a need to raise a gate for clearing debris, the riprap was designed to remain stable for extreme conditions under a very short duration. The design conditions were full open or half open single gate with normal pool and minimum tailwater. Before placement of the riprap, the maximum allowable gate openings were based on a flow velocity of 4.5 feet per second; however, for emergency purposes, it was permissible for flow velocities to go as high as 6.0 feet per second. Because of the additional channel stability, the maximum outflow velocity for routine gate movements was raised to 6.0 feet per second, and under emergency situations, this velocity may be exceeded for brief periods (i.e. 15 to 20 minutes). Therefore, a new Gate Regulation Schedule was developed showing the new maximum allowable gate openings.

e. 1988 Modification. The motors that operate the lock miter gates were raised in 1988. Before this, the motors were pulled when the pool reached elevation 681.0 feet (1912 adjustment). Since the motors were raised, the lock does not technically go out of operation until the pool is at the top of the upstream miter gates at elevation 683.0 feet.

f. 1995 Modification. Historically, winter regulation allowed for a tolerance of plus or minus 0.3-foot above or below the project pool elevation at the primary control point. This was for the purpose of providing for delays in gate operations due to ice. The Water Level Management Task Force, which is a subcommittee of the River Resource Forum, is a multi-agency group that shares information and provides suggestions on river management (see **Section 9-02.e. River Resources Forum**). In 1995 the Task Force requested that Water Control hold the Mississippi River pools on the high side of the band during winter regulation on a trial basis. Therefore, starting in the winter of 1995, the primary control point at Prescott was maintained between elevations 675.0 feet and 675.3 feet (1912 adjustment). The purpose was to keep as much volume of water as possible in the backwater areas to avoid or delay dissolved oxygen depletion during the winter. The plan was implemented every year since and became official in the year 2000 when it was incorporated as a routine part of the operating plan.

g. 2003 Modification. Changes in the Operating Curves and a check of Roller Gate end sill velocities necessitated minor modifications to the existing Gate Regulation Schedule. A new Gate Regulation Schedule (**Table 7-4**) was developed based on these findings.

3-06. Principal Regulation Problems.

a. Spot Dikes. There are multiple spot dikes that were constructed by the Corps of Engineers to close off side channels and sloughs on the Wisconsin side of the river upstream of the dam. Spot Dike A begins immediately upstream of the dam on the left bank and over the next two miles it is followed by Spot Dikes B through J. These spot dikes were designed to maintain the pool at elevation 675.0 feet (1912 adjustment) and to overtop during high flows allowing a portion of the flow to be routed around the Wisconsin side of the dam through a series of lakes separated by privately owned dikes. The Diamond Bluff Associates, a private hunting club, owns the Gantenbein Lakes area on the Wisconsin side of Lock and Dam 3 (**Figure 3-1**). An intermediate embankment owned by Diamond Bluff Associates separates Marsh Lake from Gantenbein Lake. A lower embankment, also owned by Diamond Bluff Associates, separates Gantenbein Lake from the tailwater below Lock and Dam 3. The Spot Dikes and the Intermediate and Lower Dikes maintain a maximum head of eight feet between Pool No. 3 and the tailwater. Parts of the embankments are constructed and the rest are natural river bank levees. The three embankments are overtopped, on average, 53 days per year. The high frequency of overtopping has resulted in erosion that must be continually repaired. Also, navigation accidents could result in overtopping, erosion, and potential failure of a portion of the three embankments during high head differential conditions. The Corps of Engineers has a written agreement with the Diamond Bluff Associates to perform emergency repairs of the

Intermediate and Lower Dikes. The present agreement expires 5 February 2007. Failure of the embankment system could result in accidental drawdown of Pool No. 3, with adverse effects on the river environment, navigation, and forced shutdown of the Prairie Island and Allen King Power Plants. There presently is an on going study entitled *Lock and Dam 3 Navigation Safety and Embankments* which is evaluating the needs of the spot dike system in conjunction with the outdraft problem on navigation.

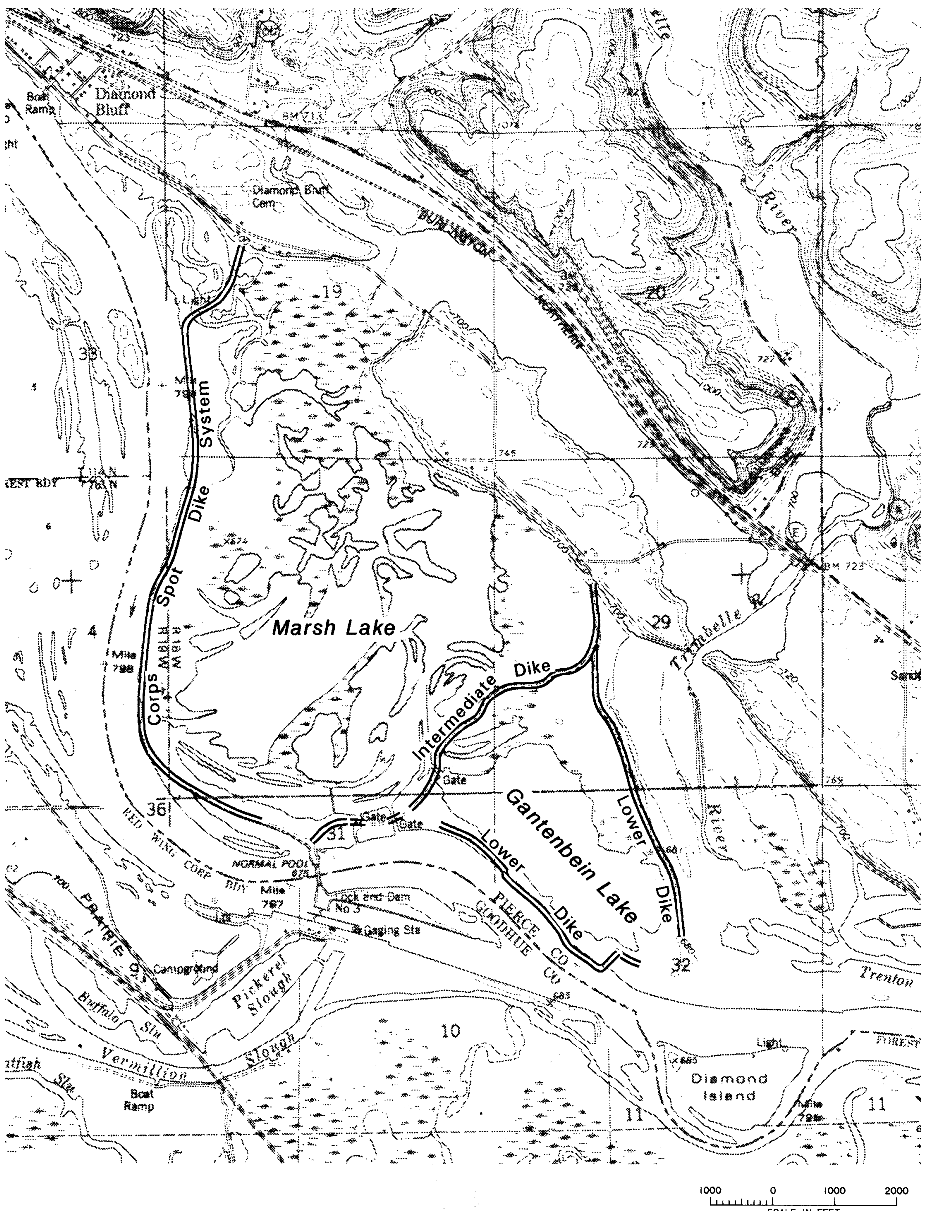

Figure 3-1. Spot Dike System and Intermediate and Lower Dikes.

b. Outdraft. An outdraft problem exists at Lock and Dam 3 primarily for down-bound tows. The location of the lock and dam on a bend in the river makes down-bound navigation difficult because of an outdraft current that sweeps towboats and barges away from the lock and toward the dam (**Figure 3-2**). The outdraft problem at Lock and Dam No. 3 is considered to be one of the worst on the Upper Mississippi River and has resulted in numerous navigation accidents. Signs are located at the end of the upper and lower guide walls to warn of outdraft when flows are above 21,000 cfs. The signs are circular, about three feet in diameter, and are orange in color. They are permanently mounted on a hinge, thereby allowing them to be swung out into view when necessary. They are illuminated by a steady orange light source. The signs are swung back in at a discharge of 20,000 cfs.

Figure 3-2. Upper Approach Outdraft at Lock and Dam No. 3

On 1 August 1993 high west winds combined with severe outdraft resulted in three barges breaking free of a 12-barge load being towed by the motor vessel Hornet. Two of the three barges eventually were flushed through the dam; however, the third barge became lodged across the bay of the first and part of the second roller gate bay. The barge had struck one of the dam piers piercing a hole into the hull and as a result the barge started sinking (**Figure 3-3**).

Figure 3-3. Barge Incident on 2 August 1993.

The blockage of available flow area cause an abrupt rise in the pool level and forced water through the spot dike system. Because of the high headwater and low tailwater, parts of the spot dike and lower dike system eroded (**Figure 3-4**). Emergency actions taken are documented in **Appendix D**.

Figure 3-4. Mississippi River at Lower Dike, 4 August 1993.

c. **Zebra Mussels.** Currently infestations of zebra mussels are not having impacts on operations at Lock and Dam No. 3. Should they reach Lock and Dam No. 3 in large numbers, it is possible that they may foul the gage wells, concrete surfaces, and untreated metal surfaces such as the lock miter gates. Masses of dead zebra mussels could accumulate in the gate recesses, hindering operation. The St. Paul District developed a "Zebra Mussel Response Plan" in November 1997. There were five methods for short-term control identified for locks and dams. The following tables show the possible problems and the recommended control techniques identified in the study.

Table 3-1
Zebra Mussel Control Techniques

Code	Method	Description
A	Physical Removal	Removed by scraping, brushing, or high-pressure water or steam spraying.
B	Mollusicides	Primarily oxidizing biocides (chlorine) with possibility of periodic use of nonoxidizing biocides.
C	Thermal Treatments	Hot water, steam, or air injection periodically to kill adult and larval zebra mussels.
D	Dewatering Dislocation	Isolation of susceptible components from the river. Components removed from river if possible.
E	Replacement Components	Replacement components which can be easily removed should infestation occur.

Table 3-2
Proposed Zebra Mussel Control Techniques for Locks and Dams

Component	Potential Problem	Method
Lock Walls	Heavy encrustations can be expected. Structural damage limited to abrasion during cleaning.	A,D
Gages	Occlusion of the pipe leading from the well to the River. Encrustation of level markings.	A,B,C,D
Thermometers	Encrustations could reduce reliability of readings.	A
Miter Gates	Increased corrosion of metal surface, paint deterioration, and unbalanced loading.	A,D
Bulkhead Slots	Accumulation along the sealing surfaces.	A,D
Lock Culverts	Reduced flow area and increased roughness could cause increased emptying and filling times.	A,D
Roller Gates	Increased gate weight and corrosion.	A,D
Side Seals	Accelerated deterioration of seals.	A,D,C,E
Tracks, Chains, Cables	Accumulation could prevent movement of roller gates. Metal and paint deterioration.	A,D

IV – WATERSHED CHARACTERISTICS

4-01. General Characteristics. Pool No. 3 is about 18 miles in length. At project pool elevation of 675.0 feet (1912 adjustment), the pool has a total surface area of 17,950 acres. The drainage area of Pool No. 3 totals 45,170 square miles in Minnesota and Wisconsin. Except for several small creeks, the only major tributary to Pool No. 3 is the St. Croix River with a total drainage area of 7,650 square miles. The St. Croix River enters the pool from the Wisconsin side of the Mississippi River approximately 14.4 miles upstream of Lock and Dam No. 3 and four miles downstream of Lock and Dam No. 2.

4-02. Topography. The Master Water Control Manual for the Locks and Dams gives a description the topography for the Upper Mississippi River basin. Presented here is a description of the topography for the St. Croix River. The St. Croix River's headwaters are at St. Croix Lake near Solon Springs, Wisconsin, from where it flows west and south over 160 miles until it joins the Mississippi River at Prescott, Wisconsin. Approximately 80 percent (129 miles) of the St. Croix River forms part of the boundary between Wisconsin and Minnesota. The upper 20 percent of the river is entirely within Wisconsin. The watershed covers 7,650 square miles and extends from near Mille Lacs Lake in Minnesota on the west to near Cable, Wisconsin, on the east. The basin encompasses all or portions of Carlton, Pine, Aitkin, Mille Lacs, Kanebec, Chisago, Isanti, Ankoa, and Washington counties in Minnesota and Douglas, Bayfield, Sawer, Washburn, Burnett, Barron, Polk, St. Croix, and Pierce counties in Wisconsin. The river originates in a region of northern spruce and pine and flows southwesterly through hardwood forests and prairie, eventually joining the Mississippi River.

During the last glacial period, about 10,000 years ago, the St. Croix River valley served as a major drainage channel for glacial meltwater from Lake Superior. As these waters carved the way for the river seen today, the waters left behind a variety of soils and sediment that cover the ancient lava bedrock far below, including a glacial outwash plain of sand left by Glacial Lake Grantsburg. Many springs along the river banks occur where the river valley has eroded through the glacial gravel to release water trapped between the sediments.

During the early days of the lumber industry in basin, the St. Croix River was used to float logs from the forests upstream of Taylors Falls to the sawmills at Stillwater. Additionally, regular steamboat service was maintained between the two communities. In 1910, a 3-foot channel was completed from Taylors Falls to the mouth of the St. Croix River. However, with the development of the railroads and highways and with the conclusion of the lumbering activities, commercial use of the waterway upstream of Stillwater decreased to almost zero, and the channel deteriorated to an effective depth of one foot or less at low water. In 1930, a 6-foot channel was authorized from the mouth of the river to Stillwater, and in the same reach of river, a 9-foot channel was established in 1938 when Lock and Dam No. 3 was placed into operation.

4-03. Sediment. Part of the nine-foot navigation plan authorized by Congress included periodic dredging of sediment. There are eight sites within the Pool No. 3 navigation channel that require periodic dredging. Quantities and frequency of dredging these areas are presented in **Paragraph 5-03**.

4-04. Climate. The National Weather Service maintains temperature and precipitation records for Lock and Dam No. 3. Pan evaporation data was collected at Lock and Dam No. 6, but stopped after 1997. The 30-Year Normal (1960-1989) Temperature and Precipitation data shown in the following tables were taken from National Oceanic and Atmospheric Administration's *Climatological Data Annual Summaries*, for Red Wing Dam 3, Minnesota. Pan evaporation was measured at Lock and Dam No. 6.

Table 4-1
30-Year Normal Monthly Temperature in Degrees Fahrenheit

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
10.7	26.3	31.9	48.8	60.6	66.8	74.5	69.1	60.0	47.0	40.8	24.2	46.7

Table 4-2 30-Year Normal Monthly Precipitation in Inches												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1.23[1/]	0.74[1/]	1.71	2.76	3.59	3.69	4.28	3.45	3.45	2.26	1.45	0.96	29.57[1/]

[1/] Based on incomplete dataset.

Table 4-3 Pan and Pool Monthly Evaporation in Inches (Lock and Dam No. 6)[1/]								
	Apr	May	Jun	Jul	Aug	Sep	Oct	Period of Record
Pan Evaporation	0.26	3.35	3.92	5.15	4.66	2.88	0.65	(1983 – 1997)
Pool Evaporation	0.18	2.35	2.74	3.61	3.26	2.02	0.46	(1983 – 1997)

[1/] Pool evaporation was estimated by assuming a pan coefficient of 0.7.

Wind speed and direction are recorded each morning at Lock and Dam No. 3. While this information is valuable for the regulation of the dam, it is of little value for presenting monthly highest wind speeds and directions. The *Climatic Atlas of the United States* (June 1968) contains monthly Fastest Mile information for La Crosse, Wisconsin (10 years of record). Fastest Mile wind speeds are defined as the fastest speed at which wind travels one mile measured over one month. Fastest Mile wind speeds are typically obtained from a short period of time, usually less than two minutes duration. The Fastest Mile wind speeds presented in the Atlas were modified to time-dependant (1-hour) average wind speeds using procedures presented in the US Army Corps of Engineers' *Shore Protection Manual* (1984).

Table 4-4 Highest Monthly Wind Speed and Direction in MPH for La Crosse, WI												
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Direction	NNW	WNW	NNW	SSW	E	NNW	N	N	SSW	WNW	S	NNW
Fastest Mile	35	36	40	50	58	60	36	46	36	38	46	43
1-Hour	29.5	30.3	33.3	41.0	46.8	47.2	30.3	37.9	30.3	31.8	37.9	38.1

Because of the bluffs along the river, winds tend to be channeled either up river or down river. The wind blowing across the pool surface exerts a horizontal force on the water surface and induces a surface current in the general direction of the wind. The horizontal currents induced by the wind essentially cause water to "pile up" on the downwind side, resulting in a water level rise downwind and a water level drop upwind. The rise in water level is due to "wind setup". This can be estimated by (EM 1110-2-1414):

$S = (U^2 F)/(1400\ D)$ Where,

S = Wind Setup (ft)
U = Wind Speed (mph)
F = Fetch Length (miles)
D = Average Depth over Fetch (ft)

The above equation neglects the time required for the full wind setup to occur. The stronger the wind, the more time required. While it is recognized that the relationship is not linear, a rule of thumb has been developed that seems to work quite well for the lock and dam pools. For each ten miles per hour of wind speed, figure the change in the pool level to be 0.1 feet. Therefore, a northern wind at 20 mph would cause a 0.2 feet rise in the water surface at the dam, and conversely, a southern wind of 10 mph would result in a lowering of the water surface at the dam by 0.1 feet.

4-05. Storms and Floods. While an isolated storm over the St. Croix River basin can have a significant impact on water levels in Pool No. 3 during low flows, it is high inflows from upstream that produce flooding of the pool. After construction of the lock and dam in 1938, the first significant flood event did not occur until the spring of 1951. On the 18th of April, the Mississippi River at Pool No. 3 crested at elevation 683.64 feet (1912 adjustment). This stage was exceeded the following year. On the 17th of April 1952, the Mississippi River at Pool No. 3 peaked at elevation 684.68 feet. The estimated discharge was 151,000 cfs. This remained the flood of record until 1965. **Table 4-5** gives a summary of peak elevations and discharges followed by a brief description of some of the larger events. The flood of record was in April 1965. The second highest flood was in 1969 followed by 2001.

Table 4-5 **Summary of Peak Stages/Elevations and Discharges**						
Prescott, WI – Control Point			**Lock and Dam No. 3**			
Date	Stage Ft	Elev. ft (1912)	Date	Pool ft (1912)	Tailwater ft (1912)	Discharge cfs
17-Apr-51	10.13	687.47	18-Apr-51	683.64	683.11	-
17-Apr-52	11.69	689.03	17-Apr-52	684.68	684.14	151,000
18-Apr-65	**15.77**	**693.11**	**19-Apr-65**	**688.22**	**687.80**	**230,000**
17-Apr-69	14.14	691.48	17-Apr-69	686.60	686.08	192,000
28-Jun-93	10.35	687.69	28-Jun-93	683.22	682.53	128,400
13-Apr-97	12.57	689.91	13-Apr-97	685.22	684.22	159,200
28-Apr-01	13.54	690.88	28-Apr-01	686.18	685.20	173,900

a. April - May 1965. Because of the magnitude of the snow-water content on the ground, forecasts and warnings of floods were issued by the Weather Bureau (now the National Weather Service). An advisory on the flood potential in the Upper Mississippi River basin was published as early as the 19th of March 1965. The forecast predicted a stage of 18.0 feet at Hastings, (flood stage: 15.0 feet), elevation 688.0 at Stillwater (flood stage 687.0 feet), and 14.0 feet at Red Wing (flood stage: 14.0 feet) with normal precipitation and a snowmelt of more than three days. The forecast cautioned that if rainfall of one inch should occur before or during the crest, the resulting peak stages would be near the 1952 level. Moderate to heavy rains fell in early April and increased the water content of the snow on the ground to a maximum by the 6th of April. The Weather Bureau revised the forecast for the Mississippi River at Red Wing upwards to a stage of 18.5 feet and the St. Croix River at Stillwater upwards to an elevation of 692.0 feet. The forecasted discharge of almost 180,000 cfs translated into a predicted elevation of 686.0 feet (1912 adjustment) at the dam. Based on this, the earthen dike, with a crest elevation of 686.0 feet, and access roads were strengthened and raised to provide sufficient freeboard. Additional rainfall fell between the 8th and 12th of April and caused another upward revision in the forecasts for Pool No. 3. On April 15th, the official forecast for peak stages at Red Wing and Stillwater were raised to 20.5 feet and elevation 694.0 feet, respectively. The forecast for Pool No. 3 was raised to a peak stage of 688.2 feet with a discharge of 230,000 cfs. The rapid increase of inflow began on the 5th of April when the discharge rose from 15,000 cfs on this date to 31,500 cfs on the 7th of April. By this time the head at the dam had been reduced to 0.15 feet and the gates were removed from the water. The motors that operate the lock miter gates were pulled on the 12th of April and the lock was out of operation for 24 days until the 6th of May. The Mississippi River crested at elevation 686.1 feet (stage 20.97 ft) at Red Wing on the 18th of April. This was 6.97 feet above flood stage and was 4.12 feet higher than the peak stage of 1952. The pool at Lock and Dam No. 3 crested on the 18th of April at elevation 688.22 feet with a peak flow of 230,000 cfs. The pool returned to secondary control (elevation 673.0 feet in 1965) on the 28th of June and the dam was put back into operation. The St. Croix River reached bankfull stage at Stillwater on the 12th of April and crested on the 18th of April, 7.09 feet above flood stage at elevation 694.09 feet, which was nearly 4.4 feet above the previous record crest of 1952.

b. **April 1969.** The high inflows from Lock and Dam No. 2 combined with the discharge from the St. Croix River resulted in the second highest discharge at Lock and Dam No. 3. The high inflow from Lock No. 2 was due mainly to the high discharge on the Minnesota River peaking at the same time as the Mississippi River. This high inflow caused a backwater effect on the St. Croix River resulting in the second highest stage of record at Stillwater. The elevation was 694.09 feet in 1965 and elevation 692.32 feet in 1969. The pool crested on 17 April at elevation 686.60 feet. Peak discharge was 192,000 cfs.

c. **April 1997.** The magnitude of the snow-water content on the ground indicated a high potential for flooding along the Upper Mississippi River. On the 13th of March, the National Weather Service outlook predicted a stage of 20.5 feet at Hastings (flood stage: 15.0 feet), elevation 689.5 feet at Stillwater (flood stage: 687.0 feet), and a stage of 17.0 feet at Red Wing (flood stage: 14.0 feet). The Mississippi River began to rise on the 2nd of April and the crest outlook was revised on April 4th to account for above normal temperatures and anticipated rainfall in the area. The river continued to rise an average of one-foot per day until the 12th of April when it crested at 21.3 feet (elevation 691.95 feet) at Hastings and 17.1 feet (elevation 682.23 feet) at Red Wing. The pool at the dam also crested on the 12th of April at elevation 685.22 feet. Peak discharge was 159,200 cfs. The lock was out of operation from the 8th of April until the 19th of April. The St. Croix River at Stillwater crested on the 12th of April 3.45 feet above flood stage at an elevation of 690.45 feet.

d. April 2001. The National Weather Service's 2001 Spring Snowmelt Flood Outlook predicted minor to moderate flooding for Pool No. 3. This forecast was primarily due to the significant autumn precipitation the year before and the heavy winter snowfall. A less than ideal snowmelt followed by record breaking April precipitation resulted in producing the third highest flood stages in Pool No. 3. The pool reached the closure elevation of 683.0 feet on 12th of April. On the 17th of April, the pool at Lock and Dam No. 3 peaked at elevation 686.00 feet with a discharge of 171,900 cfs. However, additional rainfall resulted in a second crest of elevation 686.18 feet on the 28th of April with a discharge of 173,900 cfs. The pool did not fall below elevation 683.0 feet until the 5th of May. While the lock may have been operable before the 12th of April and after the 5th of May, the Coast Guard closed the river to navigation from the 9th of April to the 9th of May. By this time the pool had fallen to elevation 680.97 feet. The St. Croix River at Stillwater crested on the 27th of April, 5.32 feet above flood stage at an elevation of 692.32 feet.

4-06. Runoff Characteristics. The mean annual discharge at Lock and Dam No. 3 is 20,500 cfs based on a period of record from 1960 to 2002. The following table shows the monthly average discharges.

Table 4-6
Monthly Average Flow in cfs – (Years 1960 to 2002)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
9,600	9,600	19,500	47,000	36,400	27,700	22,800	15,100	14,000	16,100	16,100	11,700

A maximum discharge of 230,000 cfs occurred at the dam on 19 April 1965 (**Table 4-5**). The lowest discharge recorded before the locks and dams was 2,200 cfs during extremely low water in 1934. Very low flows occur each winter when freeze up occurs. They are typically of very short duration. The lowest winter discharge recorded was 2,400 cfs on 4 December 1976. The minimum discharge during navigation season occurred with the drought of 1988 when the discharge got as low as 1,600 cfs on 3 August 1988 and remained below 2,500 cfs from 30 July through the 4 August.

A discharge-frequency curve for the Mississippi River at Prescott, Wisconsin is shown on **Figure 8-1**. Based on discharge data recorded at the dam from 1972 through 2000, the following Discharge-Duration Table was developed. The table shows the percent of time the discharge is at or above the indicated discharge.

Table 4-7
Discharge-Duration at Lock and Dam No. 3
Percent Time At or Above Indicated Discharge (Years 1972-2000)

Discharge	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
130,000				1.0									
125,000				1.2		0.3							0.1
120,000				1.3		0.5	0.1						0.2
115,000				1.4		0.6	0.2						0.2
110,000				2.2	0.6	0.6	0.3						0.3
105,000				2.6	0.7	0.7	0.4						0.4
100,000				3.0	0.8	0.7	1.0						0.5
95,000				3.8	1.3	0.7	1.7						0.6
90,000				4.6	2.3	0.8	2.0						0.8
85,000			0.2	5.8	3.1	0.8	2.2						1.0
80,000			0.6	6.9	3.7	0.8	2.7		0.5	0.2			1.3
75,000			1.2	8.2	4.1	2.3	2.9	0.1	0.6	0.4			1.7
70,000			1.7	10.5	4.9	2.5	3.1	0.2	0.7	0.6			2.0
65,000			2.1	16.6	6.9	2.8	3.6	0.2	0.7	0.7			2.8
60,000			3.7	21.8	9.3	3.0	4.0	0.3	0.7	0.8			3.6
55,000			5.8	27.4	15.5	3.5	4.7	0.4	0.7	1.0			4.9
50,000			7.9	33.6	20.1	4.4	6.1	0.7	0.8	1.1			6.2
45,000			9.0	41.7	28.5	7.9	7.8	1.9	0.9	3.5			8.5
40,000			11.2	50.7	38.0	12.5	11.6	4.2	1.3	5.2	0.3		11.3
35,000		0.2	16.7	60.1	48.8	21.5	18.2	5.5	2.8	8.3	2.8		15.5
30,000		0.7	23.7	69.1	57.5	39.0	32.8	11.0	10.0	14.6	6.0	0.6	22.2
25,000		1.2	30.1	77.0	67.0	58.1	46.1	20.0	16.1	18.7	14.6	1.5	29.3
20,000		2.3	41.7	81.4	75.8	70.7	58.6	31.2	24.3	26.1	34.6	9.0	38.1
15,000	8.1	6.8	59.1	90.5	83.3	79.4	69.5	46.1	39.5	43.1	56.3	32.6	51.4
10,000	53.4	44.8	76.2	98.4	92.2	88.5	78.3	70.1	63.8	64.6	78.5	63.1	72.8
5,000	94.4	94.4	97.9	100.0	100.0	97.4	93.6	89.8	94.4	96.1	96.2	93.6	95.6
0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Construction of the lock and dam greatly influenced stage-duration curves throughout the pool. While it would appear stage-duration tables could be developed for the entire period of record since construction of the lock and dam, drawdown at the dam was reduced from two feet (i.e. elevation 973.0 feet) to one foot in 1971 (i.e. elevation 674.0 feet). Therefore, stage-duration tables for the pool and the primary control point (Prescott) were developed based on a period of record from 1972 to 2000. This period of record was also used for the tailwater stage-duration table. Gage zero for the pool and tailwater is elevation 665.80 feet. The Prescott gage zero is elevation 677.60 feet. All stage data were converted to elevation (1912 adjustment). The tables indicate the percent of time the water surface is at or above the indicated elevation. More detailed data are available from the Water Control website at www.mvp-wc.usace.army.mil.

Table 4-8
Elevation-Duration, Lock and Dam No. 3 Tailwater
Percent of Time at or Above Indicated Elevation (Years 1972 to 2000)

Elev.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
682.5				1.0		0.1							0.1
682.0				1.3		0.5	0.1						0.2
681.5				1.9	0.3	0.6	0.3						0.3
681.0				2.6	0.7	0.6	0.4						0.4
680.5				3.0	1.0	0.7	1.1						0.5
680.0				4.1	1.9	0.8	1.8						0.7
679.5			0.2	5.6	2.8	0.8	1.9						0.9
679.0			0.8	6.9	3.5	0.8	2.1		0.6	0.2			1.2
678.5			1.3	8.2	3.9	2.2	2.6		0.6	0.4			1.6
678.0			1.7	11.8	5.0	2.6	3.0	0.1	0.7	0.6			2.1
677.5			2.2	17.5	7.2	2.9	3.3	0.2	0.7	0.6			2.9
677.0			3.3	22.1	10.0	3.0	3.8	0.3	0.8	0.8			3.7
676.5			5.3	27.2	13.8	3.5	4.4	0.4	0.9	0.9			4.7
676.0			6.7	30.2	17.7	4.4	5.6	0.4	0.9	1.1			5.6
675.5			8.3	37.2	23.0	5.3	6.6	1.2	1.0	1.6			7.0
675.0			9.0	42.4	28.9	9.0	7.8	1.8	1.0	3.3			8.6
674.5			10.6	47.4	34.8	11.4	10.1	3.5	1.2	4.6	0.1		10.3
674.0			12.7	53.3	42.4	13.9	12.7	4.5	1.6	5.8	1.4		12.4
673.5		0.3	15.6	58.7	47.6	19.1	16.6	5.5	2.4	7.2	2.5		14.7
673.0		0.6	18.6	63.9	51.8	26.8	22.8	6.3	4.1	10.2	3.9		17.5
672.5		0.8	22.0	67.5	55.3	33.9	27.3	8.8	7.4	12.1	5.8	0.7	20.2
672.0		1.1	24.9	71.5	59.0	39.0	31.3	12.1	10.2	14.8	8.5	1.7	22.9
671.5	0.4	1.3	28.0	74.9	62.4	48.8	37.3	14.0	13.3	17.0	12.6	3.0	26.2
671.0	0.9	1.8	31.9	78.4	66.4	57.0	43.6	17.5	17.9	19.5	17.1	5.3	29.9
670.5	1.5	2.4	37.9	81.0	70.2	64.3	48.7	23.6	22.9	24.5	22.4	9.8	34.2
670.0	2.9	2.9	43.9	82.6	75.3	70.0	55.3	29.4	28.4	28.5	34.3	16.8	39.3
669.5	9.2	5.1	50.5	86.6	79.4	75.2	64.1	35.7	35.3	35.2	47.0	31.8	46.4
669.0	27.1	19.2	62.6	91.0	83.0	78.5	69.3	44.5	42.0	44.3	60.1	48.4	56.0
668.5	51.4	42.1	71.8	96.6	87.2	82.1	74.9	57.3	54.3	57.3	69.4	63.0	67.4
668.0	72.4	71.8	87.0	99.2	92.8	89.2	80.3	75.4	70.7	69.3	83.3	77.1	80.7
667.5	90.0	90.8	98.1	100.0	99.5	97.1	95.4	92.7	92.6	90.7	94.8	91.5	94.4
667.0	98.6	99.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.5	99.9	99.8
666.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Note that normal pool level for the tailwater is elevation 667.0 feet (1912 adjustment). Since 1995, Water Control has held the pools on the high side of the band during the winter months for habitat enhancement. See **Paragraph 3-05.f.** for a brief history of this. Therefore, percent of time the tailwater is at or above elevation 667.0 feet in the winter months is presently 100 percent.

Table 4-9 **Elevation-Duration for Prescott, Wisconsin** **Percent of Time at or Above Indicated Elevation (Years 1972 to 2000)**													
Elev.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
688.5				0.9									
688.0				1.2									
687.5				1.3		0.2							0.1
687.0				1.5		0.6							0.2
686.5				1.7		0.6	0.1						0.2
686.0				2.8	0.8	0.7	0.4						0.4
685.5				3.2	1.9	0.7	1.2						0.6
685.0				4.6	3.0	0.8	1.9						0.9
684.5				5.8	3.3	1.3	2.3						1.1
684.0			0.7	7.9	3.6	2.5	2.7		0.7	0.3			1.5
683.5			1.3	10.3	4.8	3.0	3.3	0.1	0.8	0.4			2.0
683.0			2.0	16.9	7.9	3.0	3.7	0.1	0.8	0.7			2.9
682.5			4.2	24.1	10.9	3.3	4.6	0.2	0.9	0.8			4.1
682.0			6.5	29.0	14.8	3.9	5.7	0.6	1.0	1.0			5.2
681.5			8.2	33.9	20.5	4.8	6.6	1.0	1.0	1.6			6.5
681.0			9.1	39.8	25.4	7.9	8.0	2.2	1.0	2.1			8.0
680.5			10.1	44.4	30.8	10.6	9.8	3.3	1.2	3.6			9.6
680.0			11.9	50.0	36.0	13.3	11.8	4.0	1.4	5.2	0.7		11.3
679.5			13.9	55.4	41.2	17.5	15.6	5.2	2.5	6.7	1.3		13.4
679.0			15.9	59.5	47.8	26.6	21.0	6.0	3.6	8.9	2.3		16.1
678.5		0.4	19.8	63.1	52.2	32.3	25.3	7.9	6.4	11.4	3.0	0.1	18.6
678.0		0.8	22.7	66.7	55.8	39.1	30.7	11.0	9.9	14.8	4.7	0.8	21.6
677.5		1.0	25.6	71.2	61.4	49.5	38.6	14.9	12.0	16.6	8.9	1.6	25.3
677.0		1.4	29.4	76.8	66.0	57.1	44.4	18.2	15.8	18.9	14.0	2.8	29.0
676.5	1.2	2.2	36.9	78.9	69.7	63.9	49.8	24.8	20.2	21.9	21.7	9.2	33.7
676.0	9.1	5.0	44.9	81.7	76.4	71.4	58.6	31.5	25.3	28.7	38.4	23.9	41.6
675.5	29.8	13.9	57.4	87.4	82.4	78.5	66.6	43.5	37.2	42.8	58.4	44.2	53.8
675.0	82.1	74.6	87.1	97.6	95.2	96.8	94.4	89.8	90.0	93.1	92.3	82.4	89.7
674.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

As with the tailwater at the dam, the control point at Prescott, Wisconsin has been held on the high side of the band during the winter months since 1995. That is, it is, it would be very rare for the control point elevation to drop below elevation 675.0 feet. Therefore, the percent of time Prescott is at or above 675.0 feet during the winter months is close to 100 percent.

Table 4-10
Elevation-Duration, Lock and Dam No. 3 Pool
Percent of Time at or Above Indicated Elevation (Years 1972 to 2000)

Elev.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
683.5				1.0									
683.0				1.3		0.3							0.1
682.5				1.4		0.6	0.1						0.2
682.0				2.1	0.3	0.6	0.2						0.3
681.5				2.7	0.7	0.7	0.4						0.4
681.0				3.3	1.1	0.7	1.1						0.5
680.5				4.3	2.3	0.8	1.8						0.8
680.0				5.4	2.9	0.8	1.9						0.9
679.5			0.5	7.0	3.6	1.7	2.1		0.6	0.3			1.3
679.0			1.1	8.3	4.0	2.5	2.7	0.1	0.7	0.4			1.7
678.5			1.7	11.7	5.2	2.7	3.0	0.3	0.8	0.6			2.2
678.0			2.3	16.9	7.1	2.9	3.3	0.7	0.9	0.7			2.9
677.5			3.9	22.0	10.4	3.0	3.9	0.8	0.9	0.8			3.8
677.0			5.5	27.2	14.0	3.6	4.5	1.0	1.0	1.0			4.8
676.5			6.7	31.0	18.0	4.0	5.6	1.1	1.0	1.1			5.7
676.0			8.2	36.8	22.5	4.9	6.6	1.8	1.0	1.3			6.9
675.5			9.5	41.9	27.9	8.0	7.8	2.9	1.4	3.7	0.1		8.6
675.0	3.7	4.0	12.6	46.6	33.2	14.0	19.8	18.0	17.4	19.9	10.3	5.2	17.1
674.5	43.2	38.5	40.1	55.9	51.6	31.0	40.1	48.8	53.0	56.9	37.2	43.4	45.0
674.0	90.4	92.3	88.9	88.6	85.8	78.4	77.3	88.4	88.1	90.7	84.6	88.1	86.8
673.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

At a flat pool elevation of 675.0 feet (project pool), the storage volume in Pool No. 3 is 43,041 acre-feet in the Mississippi River segment and 240,793 acre-feet in the St. Croix River segment. However, at moderate flows, there is a slope to the flowline that allows for a one-foot drawdown at the dam. Because the dam creates backwater up the St. Croix resulting in a large amount of storage, there are actually two reaches within the pool. Because the Prescott gage is located just down stream of the St. Croix River outlet, the river was broken into two reaches for computing storage volume. The first river reach extends from the Prescott gage upstream to Stillwater, Minnesota on the St. Croix River and picks up the Mississippi River reach between Prescott and Lock and Dam No. 2. The second reach extends from Prescott to Lock and Dam No. 3 on the Mississippi River. This method of breaking up the pool into two reaches was beneficial to calculating flows. In open river conditions when you would like to verify the tailwater rating curve for Lock and Dam No. 3, total flow can be calculated by using the Prescott rating table and adding in the discharge based on the change in storage in the Prescott to the dam reach of the river. **Tables 4-12** and **4-13** can be used to determine the storage volumes in each reach for various elevations. Assuming an elevation of 674.0 ft at Lock and Dam No. 3, elevation 675.0 at the Prescott gage, and elevation 676.0 at Stillwater, the approximate volume of Pool No. 3 would be:

Prescott to Stillwater	247,000 ac-ft
Prescott to Lock and Dam No. 3	39,000 ac-ft
	286,000 ac-ft

While it is not clear what the individual volumes are for the Mississippi River and the St. Croix River, it is approximated that a flow rate of 20,000 cfs would result in a daily exchange in storage of the Mississippi River pool and a flow rate of 124,000 cfs would result in a daily exchange in storage of the St. Croix River pool. A relationship of storage to discharge is shown on **Plate 4-1**.

Table 4-11
Storage Volume in 1,000 Ac-Ft on the St. Croix River and the Mississippi River
St. Croix River: Between Prescott, Wisconsin and Stillwater, Minnesota
Mississippi River: Between Prescott, Wisconsin and Lock and Dam No. 2

Elevation at Stillwater	Elevation at Prescott, Wisconsin																				
	687	686	685	684	683	682	681	680	679	678	677	676	675	674	673	672	671	670	669	668	667
688	393	392																			
687	384	380	376																		
686		370	366	362																	
685			357	353	349																
684				342	338	334															
683					330	326	322														
682						317	313	309													
681							304	300	297												
680								292	289	285											
679									282	278	275										
678										271	267	263									
677											261	257	253								
676												251	247	243							
675													241	237	233						
674														231	227	224					
673															222	218	215				
672																214	210	206			
671																	205	201	198		
670																		196	193	189	
669																			188	185	182
668																				181	178
667																					174

Table 4-12
Storage Volume on the Mississippi River in 1,000 Ac-Ft
Between Prescott, Wisconsin and Lock and Dam No. 3

Pool Elev	Elevation at Prescott, Wisconsin																		
at Dam 3	686	685	684	683	682	681	680	679	678	677	676	675	674	673	672	671	670	669	668
683	154	145	137																
682	148	140	132																
681	142	134	126	117	110														
680	136	129	121	113	106	98													
679	131	123	115	107	100	93	86												
678		117	109	102	94	87	81	74											
677				97	90	83	77	70											
676					86	79	73	66	61	56	52								
675						75	69	63	57	52	47	43							
674							64	58	52	47	43	39							
673								54	49	44	40	37	34						
672									46	41	37	34	31	29					
671									42	38	35	31	29	27	24				
670										36	32	29	27	25	23	21			
669											30	28	26	23	21	20	18	17	
668												26	24	22	20	18	17	16	14
667													22	20	18	17	15	14	13

4-07. Water Quality. The St. Paul District does not collect water quality information for Pool No. 3. However, as an element of the Environmental Management Program (EMP), the Corps of Engineers oversees the Long Term Resource Monitoring Program (LTRMP) of the Upper Mississippi River System. The LTRMP was implemented to provide decision makers with the information needed to maintain the Upper Mississippi River System as a viable multiple-use large river ecosystem. The LTRMP is being implemented by the US Geological Survey (USGS) in cooperation with the states of Illinois, Iowa, Minnesota, Missouri and Wisconsin with guidance and overall program responsibility by the Corps of Engineers.

4-08. Channel and Floodway Characteristics. The top of the lower lock sill elevation at Lock and Dam No. 2 is elevation 662.0 feet (landward lock) and the top of the upper lock sill elevation at Lock and Dam No. 3 is elevation 653.0 feet. Therefore, there is a 9.0-foot drop in sill elevation along the pool, which has a length of 18.3 miles as measured along the navigation channel. The navigation channel is 300 feet in width in the straight stretches, and varies from 300 feet to 550 feet in the bends. The line of navigation is shown on **Plates 2-4** through **2-6**.

4-09. Upstream Structures. Lock and Dam No. 2 is located 18.3 miles upstream of Lock and Dam No. 3. The drainage area above Lock 2 is 36,990 square miles. The lock and dam system continues upstream to the Upper St. Anthony Falls Lock and Dam located in Minneapolis, Minnesota.

4-10. Downstream Structures. Lock and Dam No. 4 is located 44.2 miles downstream of Lock and Dam No. 3. The drainage area above Lock 4 is 57,100 square miles. The lock and Dam system continues downstream to Lock and Dam No. 27 in St. Louis, Missouri; however, St. Paul District terminates with Lock No. 10.

4-11. Economic Data. Pool No. 3 lies on the Minnesota-Wisconsin border. Goodhue, Dakota, and Washington Counties lie on the Minnesota side and Pierce and St.

Croix Counties lies on the Wisconsin side. Based on the US Census Bureau, county populations have increased.

Table 4-13 County and City Populations Near Pool No. 3				
	1990	**2000**	**Difference**	**Change**
County				
Dakota, MN	275,227	355,904	80,677	29.3 %
Goodhue, MN	40,690	44,127	3,437	8.4 %
Washington, MN	145,896	201,130	55,234	37.9 %
Pierce, WI	32,765	36,804	4,039	12.3 %
St. Croix, WI	50,251	63,155	12,904	25.7 %
City				
Afton, MN	2,645	2,839	194	7.3 %
Bayport, MN	3,200	3,162	-38	-1.2 %
Hastings, MN	15,445	18,204	2,759	17.9 %
Lakeland, MN	2,000	1,917	-83	-4.2 %
Lakeland Shores, MN	291	355	64	22.0 %
Lake St. Croix, MN	1,078	1,140	62	5.4 %
St. Mary's Point, MN	339	344	5	1.5 %
Stillwater, MN	13,882	15,143	1,261	9.1 %
Hudson, WI	6,378	8,775	2,397	37.6 %
North Hudson, WI	3,101	3,463	632	11.7 %
Prescott, WI	3,243	3,764	521	16.1 %

The following table gives a break down of the employment by industry. The data were taken from the US Census Bureau's 1997 Industry Report.

Table 4-14 Employment by Industry – Counties on Pool No. 3 (1997)					
Industry	**Dakota**	**Goodhue**	**Washington**	**Pierce**	**St. Croix**
Manufacturing	17,957	5,522	9,456	942	5,867
Wholesale Trade	9,650	1,051	1,471	375	484
Retail Trade	22,202	2,390	9,304	1,047	3,053
Real Estate, Rental, Leasing	1,597	107	702	185	333
Professional, Scientific, Tech Services	4,016	286	1,180	158	754
Admin & Support, Waste Management	6,604	512	2,274	125	1,803
Education Services	305	10	165	10	60
Health Care & Social Services	7,009	764	3,251	646	787
Arts, Entertainment & Recreation	2,049	1,829	822	47	301
Accommodations & Food Services	11,244	1,623	5,543	994	1,962
Other Services	4,515	383	1,700	168	324
Totals	87,148	14,477	35,868	4,697	15,728

IV – WATERSHED CHARACTERISTICS

4-01. General Characteristics. Pool No. 3 is about 18 miles in length. At project pool elevation of 675.0 feet (1912 adjustment), the pool has a total surface area of 17,950 acres. The drainage area of Pool No. 3 totals 45,170 square miles in Minnesota and Wisconsin. Except for several small creeks, the only major tributary to Pool No. 3 is the St. Croix River with a total drainage area of 7,650 square miles. The St. Croix River enters the pool from the Wisconsin side of the Mississippi River approximately 14.4 miles upstream of Lock and Dam No. 3 and four miles downstream of Lock and Dam No. 2.

4-02. Topography. The Master Water Control Manual for the Locks and Dams gives a description the topography for the Upper Mississippi River basin. Presented here is a description of the topography for the St. Croix River. The St. Croix River's headwaters are at St. Croix Lake near Solon Springs, Wisconsin, from where it flows west and south over 160 miles until it joins the Mississippi River at Prescott, Wisconsin. Approximately 80 percent (129 miles) of the St. Croix River forms part of the boundary between Wisconsin and Minnesota. The upper 20 percent of the river is entirely within Wisconsin. The watershed covers 7,650 square miles and extends from near Mille Lacs Lake in Minnesota on the west to near Cable, Wisconsin, on the east. The basin encompasses all or portions of Carlton, Pine, Aitkin, Mille Lacs, Kanebec, Chisago, Isanti, Ankoa, and Washington counties in Minnesota and Douglas, Bayfield, Sawer, Washburn, Burnett, Barron, Polk, St. Croix, and Pierce counties in Wisconsin. The river originates in a region of northern spruce and pine and flows southwesterly through hardwood forests and prairie, eventually joining the Mississippi River.

During the last glacial period, about 10,000 years ago, the St. Croix River valley served as a major drainage channel for glacial meltwater from Lake Superior. As these waters carved the way for the river seen today, the waters left behind a variety of soils and sediment that cover the ancient lava bedrock far below, including a glacial outwash plain of sand left by Glacial Lake Grantsburg. Many springs along the river banks occur where the river valley has eroded through the glacial gravel to release water trapped between the sediments.

During the early days of the lumber industry in basin, the St. Croix River was used to float logs from the forests upstream of Taylors Falls to the sawmills at Stillwater. Additionally, regular steamboat service was maintained between the two communities. In 1910, a 3-foot channel was completed from Taylors Falls to the mouth of the St. Croix River. However, with the development of the railroads and highways and with the conclusion of the lumbering activities, commercial use of the waterway upstream of Stillwater decreased to almost zero, and the channel deteriorated to an effective depth of one foot or less at low water. In 1930, a 6-foot channel was authorized from the mouth of the river to Stillwater, and in the same reach of river, a 9-foot channel was established in 1938 when Lock and Dam No. 3 was placed into operation.

4-03. Sediment. Part of the nine-foot navigation plan authorized by Congress included periodic dredging of sediment. There are eight sites within the Pool No. 3 navigation channel that require periodic dredging. Quantities and frequency of dredging these areas are presented in **Paragraph 5-03**.

4-04. Climate. The National Weather Service maintains temperature and precipitation records for Lock and Dam No. 3. Pan evaporation data was collected at Lock and Dam No. 6, but stopped after 1997. The 30-Year Normal (1960-1989) Temperature and Precipitation data shown in the following tables were taken from National Oceanic and Atmospheric Administration's *Climatological Data Annual Summaries*, for Red Wing Dam 3, Minnesota. Pan evaporation was measured at Lock and Dam No. 6.

Table 4-1
30-Year Normal Monthly Temperature in Degrees Fahrenheit

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
10.7	26.3	31.9	48.8	60.6	66.8	74.5	69.1	60.0	47.0	40.8	24.2	46.7

Table 4-2 30-Year Normal Monthly Precipitation in Inches												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1.23[1/]	0.74[1/]	1.71	2.76	3.59	3.69	4.28	3.45	3.45	2.26	1.45	0.96	29.57[1/]

[1/] Based on incomplete dataset.

Table 4-3 Pan and Pool Monthly Evaporation in Inches (Lock and Dam No. 6)[1/]								
	Apr	May	Jun	Jul	Aug	Sep	Oct	Period of Record
Pan Evaporation	0.26	3.35	3.92	5.15	4.66	2.88	0.65	(1983 – 1997)
Pool Evaporation	0.18	2.35	2.74	3.61	3.26	2.02	0.46	(1983 – 1997)

[1/] Pool evaporation was estimated by assuming a pan coefficient of 0.7.

Wind speed and direction are recorded each morning at Lock and Dam No. 3. While this information is valuable for the regulation of the dam, it is of little value for presenting monthly highest wind speeds and directions. The *Climatic Atlas of the United States* (June 1968) contains monthly Fastest Mile information for La Crosse, Wisconsin (10 years of record). Fastest Mile wind speeds are defined as the fastest speed at which wind travels one mile measured over one month. Fastest Mile wind speeds are typically obtained from a short period of time, usually less than two minutes duration. The Fastest Mile wind speeds presented in the Atlas were modified to time-dependant (1-hour) average wind speeds using procedures presented in the US Army Corps of Engineers' *Shore Protection Manual* (1984).

Table 4-4 Highest Monthly Wind Speed and Direction in MPH for La Crosse, WI												
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Direction	NNW	WNW	NNW	SSW	E	NNW	N	N	SSW	WNW	S	NNW
Fastest Mile	35	36	40	50	58	60	36	46	36	38	46	43
1-Hour	29.5	30.3	33.3	41.0	46.8	47.2	30.3	37.9	30.3	31.8	37.9	38.1

Because of the bluffs along the river, winds tend to be channeled either up river or down river. The wind blowing across the pool surface exerts a horizontal force on the water surface and induces a surface current in the general direction of the wind. The horizontal currents induced by the wind essentially cause water to "pile up" on the downwind side, resulting in a water level rise downwind and a water level drop upwind. The rise in water level is due to "wind setup". This can be estimated by (EM 1110-2-1414):

$S = (U^2 F)/(1400 D)$ Where,

S = Wind Setup (ft)
U = Wind Speed (mph)
F = Fetch Length (miles)
D = Average Depth over Fetch (ft)

The above equation neglects the time required for the full wind setup to occur. The stronger the wind, the more time required. While it is recognized that the relationship is not linear, a rule of thumb has been developed that seems to work quite well for the lock and dam pools. For each ten miles per hour of wind speed, figure the change in the pool level to be 0.1 feet. Therefore, a northern wind at 20 mph would cause a 0.2 feet rise in the water surface at the dam, and conversely, a southern wind of 10 mph would result in a lowering of the water surface at the dam by 0.1 feet.

4-05. Storms and Floods. While an isolated storm over the St. Croix River basin can have a significant impact on water levels in Pool No. 3 during low flows, it is high inflows from upstream that produce flooding of the pool. After construction of the lock and dam in 1938, the first significant flood event did not occur until the spring of 1951. On the 18th of April, the Mississippi River at Pool No. 3 crested at elevation 683.64 feet (1912 adjustment). This stage was exceeded the following year. On the 17th of April 1952, the Mississippi River at Pool No. 3 peaked at elevation 684.68 feet. The estimated discharge was 151,000 cfs. This remained the flood of record until 1965. **Table 4-5** gives a summary of peak elevations and discharges followed by a brief description of some of the larger events. The flood of record was in April 1965. The second highest flood was in 1969 followed by 2001.

Table 4-5 Summary of Peak Stages/Elevations and Discharges						
Prescott, WI – Control Point			**Lock and Dam No. 3**			
Date	Stage Ft	Elev. ft (1912)	Date	Pool ft (1912)	Tailwater ft (1912)	Discharge cfs
17-Apr-51	10.13	687.47	18-Apr-51	683.64	683.11	-
17-Apr-52	11.69	689.03	17-Apr-52	684.68	684.14	151,000
18-Apr-65	**15.77**	**693.11**	**19-Apr-65**	**688.22**	**687.80**	**230,000**
17-Apr-69	14.14	691.48	17-Apr-69	686.60	686.08	192,000
28-Jun-93	10.35	687.69	28-Jun-93	683.22	682.53	128,400
13-Apr-97	12.57	689.91	13-Apr-97	685.22	684.22	159,200
28-Apr-01	13.54	690.88	28-Apr-01	686.18	685.20	173,900

a. April - May 1965. Because of the magnitude of the snow-water content on the ground, forecasts and warnings of floods were issued by the Weather Bureau (now the National Weather Service). An advisory on the flood potential in the Upper Mississippi River basin was published as early as the 19th of March 1965. The forecast predicted a stage of 18.0 feet at Hastings, (flood stage: 15.0 feet), elevation 688.0 at Stillwater (flood stage 687.0 feet), and 14.0 feet at Red Wing (flood stage: 14.0 feet) with normal precipitation and a snowmelt of more than three days. The forecast cautioned that if rainfall of one inch should occur before or during the crest, the resulting peak stages would be near the 1952 level. Moderate to heavy rains fell in early April and increased the water content of the snow on the ground to a maximum by the 6th of April. The Weather Bureau revised the forecast for the Mississippi River at Red Wing upwards to a stage of 18.5 feet and the St. Croix River at Stillwater upwards to an elevation of 692.0 feet. The forecasted discharge of almost 180,000 cfs translated into a predicted elevation of 686.0 feet (1912 adjustment) at the dam. Based on this, the earthen dike, with a crest elevation of 686.0 feet, and access roads were strengthened and raised to provide sufficient freeboard. Additional rainfall fell between the 8th and 12th of April and caused another upward revision in the forecasts for Pool No. 3. On April 15th, the official forecast for peak stages at Red Wing and Stillwater were raised to 20.5 feet and elevation 694.0 feet, respectively. The forecast for Pool No. 3 was raised to a peak stage of 688.2 feet with a discharge of 230,000 cfs. The rapid increase of inflow began on the 5th of April when the discharge rose from 15,000 cfs on this date to 31,500 cfs on the 7th of April. By this time the head at the dam had been reduced to 0.15 feet and the gates were removed from the water. The motors that operate the lock miter gates were pulled on the 12th of April and the lock was out of operation for 24 days until the 6th of May. The Mississippi River crested at elevation 686.1 feet (stage 20.97 ft) at Red Wing on the 18th of April. This was 6.97 feet above flood stage and was 4.12 feet higher than the peak stage of 1952. The pool at Lock and Dam No. 3 crested on the 18th of April at elevation 688.22 feet with a peak flow of 230,000 cfs. The pool returned to secondary control (elevation 673.0 feet in 1965) on the 28th of June and the dam was put back into operation. The St. Croix River reached bankfull stage at Stillwater on the 12th of April and crested on the 18th of April, 7.09 feet above flood stage at elevation 694.09 feet, which was nearly 4.4 feet above the previous record crest of 1952.

b. April 1969. The high inflows from Lock and Dam No. 2 combined with the discharge from the St. Croix River resulted in the second highest discharge at Lock and Dam No. 3. The high inflow from Lock No. 2 was due mainly to the high discharge on the Minnesota River peaking at the same time as the Mississippi River. This high inflow caused a backwater effect on the St. Croix River resulting in the second highest stage of record at Stillwater. The elevation was 694.09 feet in 1965 and elevation 692.32 feet in 1969. The pool crested on 17 April at elevation 686.60 feet. Peak discharge was 192,000 cfs.

c. April 1997. The magnitude of the snow-water content on the ground indicated a high potential for flooding along the Upper Mississippi River. On the 13th of March, the National Weather Service outlook predicted a stage of 20.5 feet at Hastings (flood stage: 15.0 feet), elevation 689.5 feet at Stillwater (flood stage: 687.0 feet), and a stage of 17.0 feet at Red Wing (flood stage: 14.0 feet). The Mississippi River began to rise on the 2nd of April and the crest outlook was revised on April 4th to account for above normal temperatures and anticipated rainfall in the area. The river continued to rise an average of one-foot per day until the 12th of April when it crested at 21.3 feet (elevation 691.95 feet) at Hastings and 17.1 feet (elevation 682.23 feet) at Red Wing. The pool at the dam also crested on the 12th of April at elevation 685.22 feet. Peak discharge was 159,200 cfs. The lock was out of operation from the 8th of April until the 19th of April. The St. Croix River at Stillwater crested on the 12th of April 3.45 feet above flood stage at an elevation of 690.45 feet.

d. April 2001. The National Weather Service's 2001 Spring Snowmelt Flood Outlook predicted minor to moderate flooding for Pool No. 3. This forecast was primarily due to the significant autumn precipitation the year before and the heavy winter snowfall. A less than ideal snowmelt followed by record breaking April precipitation resulted in producing the third highest flood stages in Pool No. 3. The pool reached the closure elevation of 683.0 feet on 12th of April. On the 17th of April, the pool at Lock and Dam No. 3 peaked at elevation 686.00 feet with a discharge of 171,900 cfs. However, additional rainfall resulted in a second crest of elevation 686.18 feet on the 28th of April with a discharge of 173,900 cfs. The pool did not fall below elevation 683.0 feet until the 5th of May. While the lock may have been operable before the 12th of April and after the 5th of May, the Coast Guard closed the river to navigation from the 9th of April to the 9th of May. By this time the pool had fallen to elevation 680.97 feet. The St. Croix River at Stillwater crested on the 27th of April, 5.32 feet above flood stage at an elevation of 692.32 feet.

4-06. Runoff Characteristics. The mean annual discharge at Lock and Dam No. 3 is 20,500 cfs based on a period of record from 1960 to 2002. The following table shows the monthly average discharges.

Table 4-6
Monthly Average Flow in cfs – (Years 1960 to 2002)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
9,600	9,600	19,500	47,000	36,400	27,700	22,800	15,100	14,000	16,100	16,100	11,700

A maximum discharge of 230,000 cfs occurred at the dam on 19 April 1965 (**Table 4-5**). The lowest discharge recorded before the locks and dams was 2,200 cfs during extremely low water in 1934. Very low flows occur each winter when freeze up occurs. They are typically of very short duration. The lowest winter discharge recorded was 2,400 cfs on 4 December 1976. The minimum discharge during navigation season occurred with the drought of 1988 when the discharge got as low as 1,600 cfs on 3 August 1988 and remained below 2,500 cfs from 30 July through the 4 August.

A discharge-frequency curve for the Mississippi River at Prescott, Wisconsin is shown on **Figure 8-1**. Based on discharge data recorded at the dam from 1972 through 2000, the following Discharge-Duration Table was developed. The table shows the percent of time the discharge is at or above the indicated discharge.

Table 4-7
Discharge-Duration at Lock and Dam No. 3
Percent Time At or Above Indicated Discharge (Years 1972-2000)

Discharge	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
130,000				1.0									
125,000				1.2		0.3							0.1
120,000				1.3		0.5	0.1						0.2
115,000				1.4		0.6	0.2						0.2
110,000				2.2	0.6	0.6	0.3						0.3
105,000				2.6	0.7	0.7	0.4						0.4
100,000				3.0	0.8	0.7	1.0						0.5
95,000				3.8	1.3	0.7	1.7						0.6
90,000				4.6	2.3	0.8	2.0						0.8
85,000			0.2	5.8	3.1	0.8	2.2						1.0
80,000			0.6	6.9	3.7	0.8	2.7		0.5	0.2			1.3
75,000			1.2	8.2	4.1	2.3	2.9	0.1	0.6	0.4			1.7
70,000			1.7	10.5	4.9	2.5	3.1	0.2	0.7	0.6			2.0
65,000			2.1	16.6	6.9	2.8	3.6	0.2	0.7	0.7			2.8
60,000			3.7	21.8	9.3	3.0	4.0	0.3	0.7	0.8			3.6
55,000			5.8	27.4	15.5	3.5	4.7	0.4	0.7	1.0			4.9
50,000			7.9	33.6	20.1	4.4	6.1	0.7	0.8	1.1			6.2
45,000			9.0	41.7	28.5	7.9	7.8	1.9	0.9	3.5			8.5
40,000			11.2	50.7	38.0	12.5	11.6	4.2	1.3	5.2	0.3		11.3
35,000		0.2	16.7	60.1	48.8	21.5	18.2	5.5	2.8	8.3	2.8		15.5
30,000		0.7	23.7	69.1	57.5	39.0	32.8	11.0	10.0	14.6	6.0	0.6	22.2
25,000		1.2	30.1	77.0	67.0	58.1	46.1	20.0	16.1	18.7	14.6	1.5	29.3
20,000		2.3	41.7	81.4	75.8	70.7	58.6	31.2	24.3	26.1	34.6	9.0	38.1
15,000	8.1	6.8	59.1	90.5	83.3	79.4	69.5	46.1	39.5	43.1	56.3	32.6	51.4
10,000	53.4	44.8	76.2	98.4	92.2	88.5	78.3	70.1	63.8	64.6	78.5	63.1	72.8
5,000	94.4	94.4	97.9	100.0	100.0	97.4	93.6	89.8	94.4	96.1	96.2	93.6	95.6
0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Construction of the lock and dam greatly influenced stage-duration curves throughout the pool. While it would appear stage-duration tables could be developed for the entire period of record since construction of the lock and dam, drawdown at the dam was reduced from two feet (i.e. elevation 973.0 feet) to one foot in 1971 (i.e. elevation 674.0 feet). Therefore, stage-duration tables for the pool and the primary control point (Prescott) were developed based on a period of record from 1972 to 2000. This period of record was also used for the tailwater stage-duration table. Gage zero for the pool and tailwater is elevation 665.80 feet. The Prescott gage zero is elevation 677.60 feet. All stage data were converted to elevation (1912 adjustment). The tables indicate the percent of time the water surface is at or above the indicated elevation. More detailed data are available from the Water Control website at www.mvp-wc.usace.army.mil.

Table 4-8
Elevation-Duration, Lock and Dam No. 3 Tailwater
Percent of Time at or Above Indicated Elevation (Years 1972 to 2000)

Elev.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
682.5				1.0		0.1							0.1
682.0				1.3		0.5	0.1						0.2
681.5				1.9	0.3	0.6	0.3						0.3
681.0				2.6	0.7	0.6	0.4						0.4
680.5				3.0	1.0	0.7	1.1						0.5
680.0				4.1	1.9	0.8	1.8						0.7
679.5			0.2	5.6	2.8	0.8	1.9						0.9
679.0			0.8	6.9	3.5	0.8	2.1		0.6	0.2			1.2
678.5			1.3	8.2	3.9	2.2	2.6		0.6	0.4			1.6
678.0			1.7	11.8	5.0	2.6	3.0	0.1	0.7	0.6			2.1
677.5			2.2	17.5	7.2	2.9	3.3	0.2	0.7	0.6			2.9
677.0			3.3	22.1	10.0	3.0	3.8	0.3	0.8	0.8			3.7
676.5			5.3	27.2	13.8	3.5	4.4	0.4	0.9	0.9			4.7
676.0			6.7	30.2	17.7	4.4	5.6	0.4	0.9	1.1			5.6
675.5			8.3	37.2	23.0	5.3	6.6	1.2	1.0	1.6			7.0
675.0			9.0	42.4	28.9	9.0	7.8	1.8	1.0	3.3			8.6
674.5			10.6	47.4	34.8	11.4	10.1	3.5	1.2	4.6	0.1		10.3
674.0			12.7	53.3	42.4	13.9	12.7	4.5	1.6	5.8	1.4		12.4
673.5		0.3	15.6	58.7	47.6	19.1	16.6	5.5	2.4	7.2	2.5		14.7
673.0		0.6	18.6	63.9	51.8	26.8	22.8	6.3	4.1	10.2	3.9		17.5
672.5		0.8	22.0	67.5	55.3	33.9	27.3	8.8	7.4	12.1	5.8	0.7	20.2
672.0		1.1	24.9	71.5	59.0	39.0	31.3	12.1	10.2	14.8	8.5	1.7	22.9
671.5	0.4	1.3	28.0	74.9	62.4	48.8	37.3	14.0	13.3	17.0	12.6	3.0	26.2
671.0	0.9	1.8	31.9	78.4	66.4	57.0	43.6	17.5	17.9	19.5	17.1	5.3	29.9
670.5	1.5	2.4	37.9	81.0	70.2	64.3	48.7	23.6	22.9	24.5	22.4	9.8	34.2
670.0	2.9	2.9	43.9	82.6	75.3	70.0	55.3	29.4	28.4	28.5	34.3	16.8	39.3
669.5	9.2	5.1	50.5	86.6	79.4	75.2	64.1	35.7	35.3	35.2	47.0	31.8	46.4
669.0	27.1	19.2	62.6	91.0	83.0	78.5	69.3	44.5	42.0	44.3	60.1	48.4	56.0
668.5	51.4	42.1	71.8	96.6	87.2	82.1	74.9	57.3	54.3	57.3	69.4	63.0	67.4
668.0	72.4	71.8	87.0	99.2	92.8	89.2	80.3	75.4	70.7	69.3	83.3	77.1	80.7
667.5	90.0	90.8	98.1	100.0	99.5	97.1	95.4	92.7	92.6	90.7	94.8	91.5	94.4
667.0	98.6	99.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.5	99.9	99.8
666.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Note that normal pool level for the tailwater is elevation 667.0 feet (1912 adjustment). Since 1995, Water Control has held the pools on the high side of the band during the winter months for habitat enhancement. See **Paragraph 3-05.f.** for a brief history of this. Therefore, percent of time the tailwater is at or above elevation 667.0 feet in the winter months is presently 100 percent.

Table 4-9
Elevation-Duration for Prescott, Wisconsin
Percent of Time at or Above Indicated Elevation (Years 1972 to 2000)

Elev.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
688.5				0.9									
688.0				1.2									
687.5				1.3		0.2							0.1
687.0				1.5		0.6							0.2
686.5				1.7		0.6	0.1						0.2
686.0				2.8	0.8	0.7	0.4						0.4
685.5				3.2	1.9	0.7	1.2						0.6
685.0				4.6	3.0	0.8	1.9						0.9
684.5				5.8	3.3	1.3	2.3						1.1
684.0			0.7	7.9	3.6	2.5	2.7		0.7	0.3			1.5
683.5			1.3	10.3	4.8	3.0	3.3	0.1	0.8	0.4			2.0
683.0			2.0	16.9	7.9	3.0	3.7	0.1	0.8	0.7			2.9
682.5			4.2	24.1	10.9	3.3	4.6	0.2	0.9	0.8			4.1
682.0			6.5	29.0	14.8	3.9	5.7	0.6	1.0	1.0			5.2
681.5			8.2	33.9	20.5	4.8	6.6	1.0	1.0	1.6			6.5
681.0			9.1	39.8	25.4	7.9	8.0	2.2	1.0	2.1			8.0
680.5			10.1	44.4	30.8	10.6	9.8	3.3	1.2	3.6			9.6
680.0			11.9	50.0	36.0	13.3	11.8	4.0	1.4	5.2	0.7		11.3
679.5			13.9	55.4	41.2	17.5	15.6	5.2	2.5	6.7	1.3		13.4
679.0			15.9	59.5	47.8	26.6	21.0	6.0	3.6	8.9	2.3		16.1
678.5		0.4	19.8	63.1	52.2	32.3	25.3	7.9	6.4	11.4	3.0	0.1	18.6
678.0		0.8	22.7	66.7	55.8	39.1	30.7	11.0	9.9	14.8	4.7	0.8	21.6
677.5		1.0	25.6	71.2	61.4	49.5	38.6	14.9	12.0	16.6	8.9	1.6	25.3
677.0		1.4	29.4	76.8	66.0	57.1	44.4	18.2	15.8	18.9	14.0	2.8	29.0
676.5	1.2	2.2	36.9	78.9	69.7	63.9	49.8	24.8	20.2	21.9	21.7	9.2	33.7
676.0	9.1	5.0	44.9	81.7	76.4	71.4	58.6	31.5	25.3	28.7	38.4	23.9	41.6
675.5	29.8	13.9	57.4	87.4	82.4	78.5	66.6	43.5	37.2	42.8	58.4	44.2	53.8
675.0	82.1	74.6	87.1	97.6	95.2	96.8	94.4	89.8	90.0	93.1	92.3	82.4	89.7
674.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

As with the tailwater at the dam, the control point at Prescott, Wisconsin has been held on the high side of the band during the winter months since 1995. That is, it is, it would be very rare for the control point elevation to drop below elevation 675.0 feet. Therefore, the percent of time Prescott is at or above 675.0 feet during the winter months is close to 100 percent.

Table 4-10
Elevation-Duration, Lock and Dam No. 3 Pool
Percent of Time at or Above Indicated Elevation (Years 1972 to 2000)

Elev.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
683.5				1.0									
683.0				1.3		0.3							0.1
682.5				1.4		0.6	0.1						0.2
682.0				2.1	0.3	0.6	0.2						0.3
681.5				2.7	0.7	0.7	0.4						0.4
681.0				3.3	1.1	0.7	1.1						0.5
680.5				4.3	2.3	0.8	1.8						0.8
680.0				5.4	2.9	0.8	1.9						0.9
679.5			0.5	7.0	3.6	1.7	2.1		0.6	0.3			1.3
679.0			1.1	8.3	4.0	2.5	2.7	0.1	0.7	0.4			1.7
678.5			1.7	11.7	5.2	2.7	3.0	0.3	0.8	0.6			2.2
678.0			2.3	16.9	7.1	2.9	3.3	0.7	0.9	0.7			2.9
677.5			3.9	22.0	10.4	3.0	3.9	0.8	0.9	0.8			3.8
677.0			5.5	27.2	14.0	3.6	4.5	1.0	1.0	1.0			4.8
676.5			6.7	31.0	18.0	4.0	5.6	1.1	1.0	1.1			5.7
676.0			8.2	36.8	22.5	4.9	6.6	1.8	1.0	1.3			6.9
675.5			9.5	41.9	27.9	8.0	7.8	2.9	1.4	3.7	0.1		8.6
675.0	3.7	4.0	12.6	46.6	33.2	14.0	19.8	18.0	17.4	19.9	10.3	5.2	17.1
674.5	43.2	38.5	40.1	55.9	51.6	31.0	40.1	48.8	53.0	56.9	37.2	43.4	45.0
674.0	90.4	92.3	88.9	88.6	85.8	78.4	77.3	88.4	88.1	90.7	84.6	88.1	86.8
673.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

At a flat pool elevation of 675.0 feet (project pool), the storage volume in Pool No. 3 is 43,041 acre-feet in the Mississippi River segment and 240,793 acre-feet in the St. Croix River segment. However, at moderate flows, there is a slope to the flowline that allows for a one-foot drawdown at the dam. Because the dam creates backwater up the St. Croix resulting in a large amount of storage, there are actually two reaches within the pool. Because the Prescott gage is located just down stream of the St. Croix River outlet, the river was broken into two reaches for computing storage volume. The first river reach extends from the Prescott gage upstream to Stillwater, Minnesota on the St. Croix River and picks up the Mississippi River reach between Prescott and Lock and Dam No. 2. The second reach extends from Prescott to Lock and Dam No. 3 on the Mississippi River. This method of breaking up the pool into two reaches was beneficial to calculating flows. In open river conditions when you would like to verify the tailwater rating curve for Lock and Dam No. 3, total flow can be calculated by using the Prescott rating table and adding in the discharge based on the change in storage in the Prescott to the dam reach of the river. **Tables 4-12** and **4-13** can be used to determine the storage volumes in each reach for various elevations. Assuming an elevation of 674.0 ft at Lock and Dam No. 3, elevation 675.0 at the Prescott gage, and elevation 676.0 at Stillwater, the approximate volume of Pool No. 3 would be:

Prescott to Stillwater	247,000 ac-ft
Prescott to Lock and Dam No. 3	39,000 ac-ft
	286,000 ac-ft

While it is not clear what the individual volumes are for the Mississippi River and the St. Croix River, it is approximated that a flow rate of 20,000 cfs would result in a daily exchange in storage of the Mississippi River pool and a flow rate of 124,000 cfs would result in a daily exchange in storage of the St. Croix River pool. A relationship of storage to discharge is shown on **Plate 4-1**.

Table 4-11
Storage Volume in 1,000 Ac-Ft on the St. Croix River and the Mississippi River
St. Croix River: Between Prescott, Wisconsin and Stillwater, Minnesota
Mississippi River: Between Prescott, Wisconsin and Lock and Dam No. 2

Elevation at	**Elevation at Prescott, Wisconsin**																				
Stillwater	687	686	685	684	683	682	681	680	679	678	677	676	675	674	673	672	671	670	669	668	667
688	393	392																			
687	384	380	376																		
686		370	366	362																	
685			357	353	349																
684				342	338	334															
683					330	326	322														
682						317	313	309													
681							304	300	297												
680								292	289	285											
679									282	278	275										
678										271	267	263									
677											261	257	253								
676												251	247	243							
675													241	237	233						
674														231	227	224					
673															222	218	215				
672																214	210	206			
671																	205	201	198		
670																		196	193	189	
669																			188	185	182
668																				181	178
667																					174

Table 4-12
Storage Volume on the Mississippi River in 1,000 Ac-Ft
Between Prescott, Wisconsin and Lock and Dam No. 3

Pool Elev	**Elevation at Prescott, Wisconsin**																	
at Dam 3	686	685	684	683	682	681	680	679	678	677	676	675	674	673	672	671	670	669	668
683	154	145	137																
682	148	140	132																
681	142	134	126	117	110														
680	136	129	121	113	106	98													
679	131	123	115	107	100	93	86												
678		117	109	102	94	87	81	74											
677				97	90	83	77	70											
676					86	79	73	66	61	56	52								
675						75	69	63	57	52	47	43							
674							64	58	52	47	43	39							
673								54	49	44	40	37	34						
672									46	41	37	34	31	29					
671									42	38	35	31	29	27	24				
670										36	32	29	27	25	23	21			
669											30	28	26	23	21	20	18	17	
668												26	24	22	20	18	17	16	14
667													22	20	18	17	15	14	13

4-07. Water Quality. The St. Paul District does not collect water quality information for Pool No. 3. However, as an element of the Environmental Management Program (EMP), the Corps of Engineers oversees the Long Term Resource Monitoring Program (LTRMP) of the Upper Mississippi River System. The LTRMP was implemented to provide decision makers with the information needed to maintain the Upper Mississippi River System as a viable multiple-use large river ecosystem. The LTRMP is being implemented by the US Geological Survey (USGS) in cooperation with the states of Illinois, Iowa, Minnesota, Missouri and Wisconsin with guidance and overall program responsibility by the Corps of Engineers.

4-08. Channel and Floodway Characteristics. The top of the lower lock sill elevation at Lock and Dam No. 2 is elevation 662.0 feet (landward lock) and the top of the upper lock sill elevation at Lock and Dam No. 3 is elevation 653.0 feet. Therefore, there is a 9.0-foot drop in sill elevation along the pool, which has a length of 18.3 miles as measured along the navigation channel. The navigation channel is 300 feet in width in the straight stretches, and varies from 300 feet to 550 feet in the bends. The line of navigation is shown on **Plates 2-4** through **2-6**.

4-09. Upstream Structures. Lock and Dam No. 2 is located 18.3 miles upstream of Lock and Dam No. 3. The drainage area above Lock 2 is 36,990 square miles. The lock and dam system continues upstream to the Upper St. Anthony Falls Lock and Dam located in Minneapolis, Minnesota.

4-10. Downstream Structures. Lock and Dam No. 4 is located 44.2 miles downstream of Lock and Dam No. 3. The drainage area above Lock 4 is 57,100 square miles. The lock and Dam system continues downstream to Lock and Dam No. 27 in St. Louis, Missouri; however, St. Paul District terminates with Lock No. 10.

4-11. Economic Data. Pool No. 3 lies on the Minnesota-Wisconsin border. Goodhue, Dakota, and Washington Counties lie on the Minnesota side and Pierce and St.

Croix Counties lies on the Wisconsin side. Based on the US Census Bureau, county populations have increased.

Table 4-13 County and City Populations Near Pool No. 3				
	1990	**2000**	**Difference**	**Change**
County				
Dakota, MN	275,227	355,904	80,677	29.3 %
Goodhue, MN	40,690	44,127	3,437	8.4 %
Washington, MN	145,896	201,130	55,234	37.9 %
Pierce, WI	32,765	36,804	4,039	12.3 %
St. Croix, WI	50,251	63,155	12,904	25.7 %
City				
Afton, MN	2,645	2,839	194	7.3 %
Bayport, MN	3,200	3,162	-38	-1.2 %
Hastings, MN	15,445	18,204	2,759	17.9 %
Lakeland, MN	2,000	1,917	-83	-4.2 %
Lakeland Shores, MN	291	355	64	22.0 %
Lake St. Croix, MN	1,078	1,140	62	5.4 %
St. Mary's Point, MN	339	344	5	1.5 %
Stillwater, MN	13,882	15,143	1,261	9.1 %
Hudson, WI	6,378	8,775	2,397	37.6 %
North Hudson, WI	3,101	3,463	632	11.7 %
Prescott, WI	3,243	3,764	521	16.1 %

The following table gives a break down of the employment by industry. The data were taken from the US Census Bureau's 1997 Industry Report.

Table 4-14 Employment by Industry – Counties on Pool No. 3 (1997)					
Industry	**Dakota**	**Goodhue**	**Washington**	**Pierce**	**St. Croix**
Manufacturing	17,957	5,522	9,456	942	5,867
Wholesale Trade	9,650	1,051	1,471	375	484
Retail Trade	22,202	2,390	9,304	1,047	3,053
Real Estate, Rental, Leasing	1,597	107	702	185	333
Professional, Scientific, Tech Services	4,016	286	1,180	158	754
Admin & Support, Waste Management	6,604	512	2,274	125	1,803
Education Services	305	10	165	10	60
Health Care & Social Services	7,009	764	3,251	646	787
Arts, Entertainment & Recreation	2,049	1,829	822	47	301
Accommodations & Food Services	11,244	1,623	5,543	994	1,962
Other Services	4,515	383	1,700	168	324
Totals	87,148	14,477	35,868	4,697	15,728

V - DATA COLLECTION AND COMMUNICATION NETWORKS

5-01. Hydrometeorological Stations.

a. Facilities. The regulation and proper operation of the dam site requires the collection and evaluation of several hydraulic and hydrologic parameters. The Corps of Engineers (COE), US Geological Survey (USGS), and the National Weather Service (NWS) are involved in the data collection network. The COE monitors wind speed and direction via an anemometer located on the roof of the Central Control Station (CCS on **page iii**). The CCS houses a measuring rod for snow depth and a snow tube and scale for determining snow-water content. The site has COE and NWS precipitation gages located on the riverward lock wall. The COE gage is a standard 8-inch rain gage (**Figure 5-1**), whereas the NWS gage is a Fisher-Porter automatic weighing, punched tape, binary decimal recording gage (**Figure 5-2**).

Figure 5-1. COE Rain Gage.

Figure 5-2. NWS Rain Gage

Three water temperature sensors are located along the moveable dam. The sensors are owned by Xcel Energy Corporation to help monitor river temperatures below the Prairie Island Nuclear Power Plant (**Plate 2-6**). A digital readout of the water temperatures is presented in the Central Control Station; however, it is often malfunctioning, therefore daily temperatures recorded at the site are obtained by calling the power plant. There are six stream gages necessary for the regulation of Lock and Dam No. 3; (1) tailwater gage, (2) pool gage, (3) control point gage at Prescott, Wisconsin, (4) Stillwater gage on the St. Croix River, (5) St. Croix Falls gage on the St. Croix River, and (6) Apple River Falls Dam on the Apple River. The main interest in the first four gages is stage, whereas the main interest for the last two gages is discharge. The location of these six gages is shown on **Plate 5-1**. The following briefly describes each gage location followed by a table summarizing the equipment types and locations.

(1) Pool and Tailwater Gages. The pool gage is located on the riverward lock wall just upstream of the auxiliary miter gate (**Figures 5-1** and **5-3**). The tailwater gage (**Figure 5-4**) is located about 500 feet downstream of the moveable dam on the north shore of the island that separates the moveable dam from the lock (**Figure 2-1**).

Figure 5-3. Pool Gage House.

Figure 5-4. TW Gage House.

Both gage houses have a well with a float and tape system that reports elevation to a Stevens PAC-C Recorder (**Figure 5-5**) located in the lock house. There are two tapes in each house. The additional tape is used to verify the other.

Figure 5-5. Stevens PAV-C Strip Chart Recorders

(2) Control Point Gage. The gage at the control point is located about 3.7 miles downstream of Lock and Dam No. 2 at river mile 811.4 on the left bank near the confluence with the St. Croix River in the town of Prescott, Wisconsin (**Figure 5-6**).

Figure 5-6. Control Point Gage House – Prescott, Wisconsin

The water surface elevation is determined by a float that sits in a stilling well and is attached to a tape. The site is a Data Collection Platform (DCP). It has a Sutron 8210 Data Logger with GOES Telemetry and voice modem. The GOES Telemetry allows communication with the satellite system that provides hourly water surface elevations to Water Control. The voice modem allows telephone communication with the gage to obtain an instantaneous water surface elevation. The gage system runs on 12-volt DC power with an AC battery charger. There is a manually operated electronic tape gage inside the gage house that is used to verify the gage elevation. A staff gage is located along the outside of the gage house. The equipment is owned by the COE; however, it is maintained by the USGS through a cooperative agreement. The USGS rating table for the site is shown in **Exhibit B**.

(3) Stillwater Gage. Pool No. 3 extends up the St. Croix River to Stillwater, Minnesota (**Plate 5-1**). The gage house at this site is a steel box mounted mid-span on the downstream side of the Highway No. 36 Bridge (Stillwater Swing Bridge) over the St. Croix River (**Figure 5-7 and 5-8**) at river mile 23.4. A 6-foot channel is maintained between the Mississippi River and Stillwater. The gage is used to monitor water levels for storage volumes and navigation in the St. Croix River. The gage is a Data Collection Platform (DCP). It is equipped with a Sutron 8210 Data Logger and has GOES Telemetry and voice modem. The GOES system allows Water Control access to hourly-transmitted data via satellite. For instantaneous water surface elevations, the voice modem can be used. Water levels are determined via a Design Analysis Smart Gas system (i.e. pressure transducer). The gage system is DC powered by a battery, which is charged by a solar panel. There is a wire weight gage mounted on the downstream right side of the bridge that is used to verify the gage elevation. In addition, the site has a water temperature gage reading hourly in degrees Fahrenheit. All of the equipment is owned by the COE and maintained by the Water Control Gage Crew.

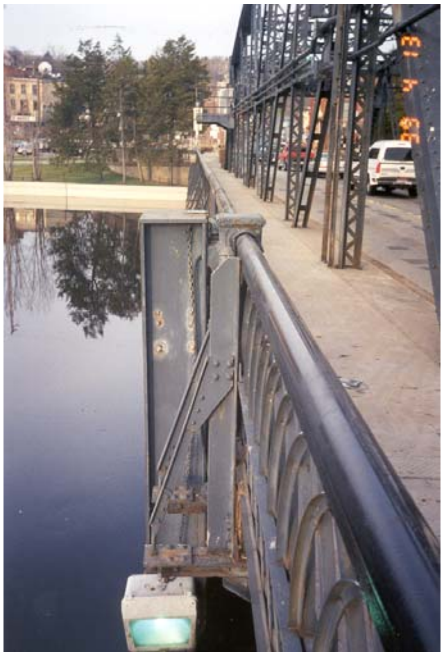

Figure 5-7. Stillwater Gage, Looking West.

Figure 5-8. Stillwater Gage, Looking East.

(4) Other Gages. The Stillwater gage is located within the backwater of Lock and Dam No. 3; therefore, to determine discharge rates on the St. Croix River, a gage was needed upstream. The gage is located about 29 miles upstream of the Stillwater gage at St. Croix Falls. It is on the left bank 1,500 feet downstream of the Northern States Power Plant in St. Croix Falls at river mile 52.2 (**Plate 5-1**). The site is a Data Collection Platform (DCP) equipped with a Campbell CR10X data logger, a pressure transducer, and GOES Telemetry thus making hourly data available to Water Control. Gage zero is elevation 689.94 feet (NGVD 1929). All of the equipment is owned by the COE; however, the site is serviced by the USGS as part of the "co-op" stream gage network. Discharge at the site is available from the Minnesota USGS web site. In addition, every day operators report the 24-hour average discharge to Water Control via remote computer. A rating table for the site is shown in **Exhibit C**. As a back up to this gage, an additional gage is located at Grantsburg, Wisconsin. The site is about 25 miles upstream of the St. Croix Falls gage. This site is also a DCP equipped with a Sutron 8200 data logger, a stilling well, and GOES Telemetry. Gage zero is 848.98 feet (NGVD 1929). The Water Control Gage Crew maintains the gage.

The Apple River Falls Dam is located about one mile upstream of the mouth of the Apple River (**Plate 5-1**). While there is no stage information available for the site, the importance of this gage site is discharge. Operators at the dam report discharge to Water Control via remote computer every morning. The discharge from the Apple River Falls Dam plus the 24-hour average discharge from St. Croix Falls Dam gives an indication of the total inflow from the St. Croix River.

Table 5-1
Hydrometeorological Stations Summary

Location	Data Type	Equipment	Notes
Prescott, Wisconsin Mississippi River Control Point	Water Surface Elevation and Stage	Sutron 8210 Data Recorder Stilling Well GOES Telemetry Voice Modem Staff Gage	Gage Zero: 650.0 (1912) NWS ID: PREW3 River Mile 811.4 Co-Op Gage
Stillwater, Minnesota St. Croix River	Water Surface Elevation and Water Temperature	Sutron 8210 Data Recorder Pressure Transducer GOES Telemetry Wire Weight Gage Voice Modem Water Temperature Sensor	Gage Zero: 600.00 (1912) NWS ID: STLM5 River Mile 23.4 Maintained by COE
Lock & Dam No. 3 Riverward Lock Wall	Pool Elevation	Stevens PAV-C Recorder Stilling Well Staff Gage	Continuous Strip Chart record Gage zero: 665.80 ft (1912)
Lock & Dam No. 3 North Bank of Island	Tailwater Elevation	Stevens PAV-C Recorder Stilling Well Staff Gage	Continuous Strip Chart record. Gage zero: 665.80 ft (1912) NWS ID: RDWM5
Lock & Dam No. 3 Central Control Station	Snow Depth & Water Content	Snow Rod Snow Tube Scale	Maintained by Water Control Gage Crew.
Lock & Dam No. 3 Riverward Lock Wall	Precipitation	Standard 8-inch Rain Gage	Recorded daily. Send data monthly to NWS Chanhassen, MN.
Lock & Dam No. 3 Riverward Lock Wall	Precipitation	Fischer-Porter – Weighted Punch Tape	NWS Gage.
Lock & Dam No. 3 Top of CCS	Wind Speed & Direction	Anemometer	Maintained by site personnel.
Lock & Dam No. 3 Movable Dam (three locations)	Water Temperature	Water Temperature Sensors	Transmitted to CCS and Prairie Island Nuclear Power Plant (owned and operated by Xcel Energy Corp).

b. Reporting. An Operating Log Book is kept at the lock and dam site. Data include water surface elevations at the pool, tailwater, and Prescott gage site, roller gate settings, air and water temperatures, 24-hour precipitation, and wind speed and direction. A more complete description is given in **Section 7-04.** In addition, site personnel also enter these data via a remote computer to a program called "sig-na-term". Each morning Water Control collects the 0600-hour data and compiles it with data from the past 24-hours. These data are formatted on to the Regulation Sheets. An example of the data presentation for Lock and Dam No. 3 is shown in **Paragraph 7-03 c**.

The data reported to Water Control via remote computer is input to a computer generated log sheet, which is available from the Water Control web site at www.mvp-wc.usace.army.mil. Data include pool and tailwater elevations, gate settings, and total discharge on four-hour intervals beginning at 0400-hours. Also included is the morning water surface elevation at Prescott and Stillwater. Total river discharge is calculated internally based the differential head and the gate openings. When the gates are out of the water, a tailwater rating table is used. During winter months, site personnel report the tainter valve opening. The computer automatically translates this opening to discharge and it is added to the total. Air temperature and wind speed and direction are entered on eight-hour intervals beginning at 0800-hours. The 24-precipitation total, water temperature, and max-min air temperatures are entered daily at 0800-hours. Note that all 0800-hour data are actually taken at 0600-hours.

Operators at the St. Croix Falls Dam and the Apple River Falls Dam report their discharges to Water Control via remote computer. While the Apple River site reports instantaneous discharge, the St. Croix River site reports the 24-hour average. These data are automatically read into the "Power" portion of the River Program and are printed out on the Daily Regulation Sheet as inflow from the St. Croix River.

During the winter months, percent of ice coverage over the lower pool and upper tailwater, ice thickness (observed), snow depth, and snow-water content (all in inches) are taken every Sunday and are reported to Water Control via remote computer. This information is available from the Water Control web site.

The Stevens PAV-C strip charts containing a continuous record of pool and tailwater elevations are mailed to Water Control every year where they are then periodically microfilmed.

c. Maintenance. Operation and maintenance of the pool and tailwater gages is the responsibility of the Water Control Gage Crew. Dam personnel maintain the Stevens Pav-C strip chart recorders with the Gage Crew used as a backup if necessary. The anemometer and standard precipitation gage are maintained by site personnel; however should the precipitation gage become damaged, a new one would be mailed to the site from Water Control. Repair or replacement of the snow survey equipment is the responsibility of the Gage Crew.

5-02. Water Quality Stations. There are no Corps of Engineers' water quality stations in Pool No. 3; however, site personnel may be asked, on occasion, to assist district office personnel or contractors to collect water samples and/or water quality measurements in the project area.

5-03. Sediment Stations. Suspended sediment data were collected by the US Geological Survey (USGS) at two locations on the Mississippi River and several locations on the St. Croix River between 1973 and 2001. Gage locations where these discrete samples were taken are listed in **Table 5-2**. Further information can be obtained from the USGS.

Table 5-2 Sediment Data Collection Sites			
Location	**River**	**USGS Gage #**	**Sampling Time Period**
Hastings, MN	Mississippi River	05331580	1995 to 2001
Red Wing, MN (at LD3)	Mississippi River	05344980	1973
Woodland Corner, WI	St. Croix River	05331775	1997
Danbury, WI	St. Croix River	05333500	1964 to 2001
Danbury, WI (bl Claim River)	St. Croix River	05335551	2000
Grantsburg, WI (ab Snake River)	St. Croix River	05337082	2000
Grantsburg, WI (at Hwy 70)	St. Croix River	05338650	2000
Grantsburg, WI (bl Wood River)	St. Croix River	05339015	2000
Sunrise, MN	St. Croix River	05339770	1995
Sunrise, MN (bl Sunrise River)	St. Croix River	05340200	2000
Wolf Creek, WI	St. Croix River	05340420	2000
St. Croix Falls, WI	St. Croix River	05340500	1974 to 2001
Marine on St. Croix, MN	St. Croix River	05340600	2000
Stillwater, MN	St. Croix River	05341510	2000
Hudson, WI	St. Croix River	05341552	1995
Afton, MN	St. Croix River	05341820	2000

Routine dredging of sediment is part of the nine-foot navigation plan. There are several sites in Pool No. 3 that require periodic dredging due to sedimentation. Dredging is the responsibility of the St. Paul District's Channel's and Harbors Project Office located at Fountain City, Wisconsin. Each year, as soon as the ice leaves the river, hydrographic surveys are made to get an early indication of channel conditions. After spring high water, surveys of the historic problem spots are performed. A list of problem locations throughout the St. Paul District is prioritized and either government owned or contract equipment is scheduled to dredge depending upon a number of factors. The practice of over dredging to reduce the frequency of dredging needs ceased in 1970; therefore, the dredging history begins in 1970. **Table 5-3** gives a summary of dredging in Pool No. 3 since 1970.

Table 5-3 Summary of Dredging Activity on the Mississippi River – 1970 through 2000					
Cut Name	**River Mile**	**Avg. Vol. Per Year**	**Avg. Vol. Per Job**	**Freq. of Dredging**	**Last Year Dredged**
Lower Approach L/D 2	814.9 - 815.1	2,935	22,744	13 %	1998
Prescott	810.3 - 811.7	1,463	45,352	3 %	1972
Truedale Slough	807.9 - 808.6	859	26,644	3 %	1972
Four Mile Island	807.0 - 807.9	2,206	68,388	3 %	1972
Big River	804.1 - 806.0	3,133	19,423	16 %	2000
Morgans Coulee	802.2 - 802.9	2,664	27,526	10 %	1998
Coulters Island	800.8 - 801.9	8,672	26,882	32 %	2000
Diamond Bluff	798.8 - 800.4	12,819	44,155	29 %	1998
Summary of Dredging Activity on the St. Croix River – 1970 through 2000					
Kinnickinnic Bar	6.0 – 6.5	5,454	33,812	16 %	1989
Hudson	16.1 – 17.6	5,902	182,964	3 %	1974

5-04. Recording Hydrologic Data. The Operating Log Book maintained at the site contains pool and tailwater elevations, roller gate settings, air temperature, precipitation, max-min air temperatures, water temperature, and wind speed and direction. All data received by Water Control from the dam site is compiled and archived using Hydraulic Engineering Center's Data Storage System (HEC-DSS) and is accessible from the Water Control web site: *www.mvp-wc.usace.army.mil*. Log data has been back entered into the computer files such that pool and tailwater elevations date back to construction of the lock and dam. These data are now available on the Water Control web site. **Table 5-4** shows a list of data types and the period of record available. Hourly data shown is collected by the DCP's located at Prescott, Wisconsin and Stillwater, Minnesota.

Table 5-4 Electronic Hydrologic Data Records		
Data Type	**Taken**	**Start of Record**
Pool and Tailwater Elevations	Daily	01 Aug 1935
Prescott, Wisconsin Elevations	Daily	01 Jan 1940
Discharge	Daily	01 Jan 1959
St. Croix at Stillwater Elevation	Daily	01 Jan 1937
Precipitation at LD 3	Daily	04 Jan 1988
Air Temperature	8-hour	02 Jan 1993
Max and Min Air Temp	Daily	04 Oct 1994
Wind Speed and Direction	8-hour	01 Jan 1993
Pool and TW Ice Coverage	Weekly	22 Nov 1998
Pool and TW Ice Thickness	Weekly	22 Nov 1998
Snow Depth, SWE	Weekly	22 Nov 1998
Water Temperature	Daily	31 Aug 1998
Prescott, Wisconsin Elevations	Hourly	01 Jan 1998
St. Croix at Stillwater Elevation	Hourly	01 Jan 2001

In 2001, Water Control generated electronic log sheets. The log sheets include all the data recorded by the lock and dam site. By using the data stored in DSS files, log sheets were generated dating back to January 1993. This sheets include pool and tailwater elevations, the elevation at Prescott, gate settings, and discharge on a 4-hour interval beginning at 0400-hours. The 4-hour readings for Prescott are actually taken from the DCP reports. The site only inputs the Prescott elevation in the morning. Readings taken at 8-hour intervals include wind speed and direction, and current air temperature. Daily values include the water surface elevation at Stillwater, 24-hour precipitation, max-min air temperature, and water temperature.

The daily record of max-min temperature, precipitation, weather characteristics, river stages and general remarks are recorded on National Weather Service (NWS) Form B-91. This form is mailed at the end of each month to the NWS in Chanhassen, Minnesota.

5-05. Communication Network. The communication network consists of computer terminal, T1 line, telephone, pager, facsimile, FM radio, voice modem, satellite, and the US Postal Service. Computer communication is done via e-mail, and "sig-na-term" which allows remote access to the Water Control network. When the computer is down, the transfer of data is by facsimile and telephone or FM radio. During non-duty hours on weekends and holidays, dam personnel can contact the river regulator by calling the pager number (612-660-8053). A T1 line ensures communication between Water Control and the Mississippi River Valley Division Office (MVD) in Vicksburg, Mississippi. Bulk items like Stevens PAV-C strip charts are delivered to Water Control through the postal service.

5-06. Communication with Project.

a. Regulating Office with Project Office. Dam site personnel input and transmit their data, via computer, to Water Control every day by 0630-hours. Water Control issues orders to Lock and Dam No. 3 every morning at approximately 0800-hours with the exception of weekends and holidays during the non-navigation season when orders are sent out around 0730-hours. Orders are typically delivered via e-mail; however, FM radio is available as backup, with the telephone serving as backup to the radio. Should the dam site have computer problems, such that the transfer of data is not possible, a facsimile is then sent to Water Control (651-290-5841). The Water Control river manager then enters the information into the Regulation Program and Information Management (IM) is notified of the computer problem. Communication with the project after orders are delivered is typically by telephone.

b. Between Project Office and Others. The general public has access to river level and discharge data by calling Water Control's "Corps of Engineers River Information Service" at 651-290-5861. This service provides a recording of daily stages and discharges along the Mississippi River. In addition, the Water Control web site at *www.mvp-wc.usace.army.mil* also provides river information to the general public. From this web site, the public can access current water surface elevations and discharges for the Mississippi River as well as the daily log sheets for the locks and dams. Notifications of severe weather or impending unusual conditions are handled through local law enforcement, civil defense authorities, and the National Weather Service.

5-07. Project Reporting Instructions. The project staff reports hydrologic and climatic conditions to Water Control every morning. The lock operator may make gate changes required to remain within the pool band issued by Water Control provided it is less than 10 percent of the total flow. If the pool goes out of the band after 0400-hours, no gate changes are to be made by project staff until Water Control issues its morning orders. Gate changes to aid work efforts (e.g. painting) are to be coordinated with Water Control. Problems with machinery that operate the gates are to be reported to Water Control Section and Construction-Operations Division.

5-08. Warnings. In the event of a gate failure, communications must be established as quickly as possible with the Water Control Section and the Construction-Operations Division. The installation of any bulkheads must be coordinated with Water Control.

VI – HYDROLOGIC FORECASTS

6-01. General. During periods of low flow, the gates at the dam are regulated to pass inflow under pooled conditions, while during high flow they are raised free of the water surface and except for a slight swellhead due to the effect of the piers, the dam offers little obstruction to the flow. The storage capacity created by the dam is relatively small as compared with the volume of flow and inasmuch as the dam is out of operation at high discharges, the use of the dam to control floods is not possible. The lock goes out of operation at elevation 683.0 feet (1912 adjustment) at which time water is at the top of the upstream miter gates. The timing and elevation of the crest is important for planning sand bagging operations and forecasting when the lock would go out of operation. In addition the timing on the receding limb of the hydrograph aids in determining when the lock would go back into service. In 1997, the St. Paul District developed an unsteady-flow model of the Mississippi River. The Mississippi Basin Model System utilizes the computer program UNET for forecasting purposes.

a. Role of the Corps. The St. Paul District previously relied solely on the National Weather Service (NWS) for Mississippi River forecasts. Lock and Dam No. 3 was fortunate in having a NWS forecast sites located upstream at Hastings, Minnesota and downstream at Red Wing, Minnesota. Unfortunately, the NWS forecast typically is only a five-day forecast with a projected crest height and date. The District saw a need for a model to forecast not only the time and elevation of the crest at the dam for planning sand bag operations, but also the receding limb for forecasting when the lock may go back into operation. In 1997, the District developed such a model. It is called the Mississippi Basin Model System (MBMS) and utilizes the unsteady flow program UNET. The river regulator in the Water Control Section runs the MBMS model every morning. For the flood events of 1997 and 2001, the model provided excellent predictions of when the crest would occur and when the lock would be placed back into operation. This was of great use to planning sand bagging efforts, work scheduling, and keeping the towing industry abreast of the flooding situation.

Modeling efforts as part of the Corps of Engineers Water Management System (CWMS) began in 2001. CWMS will contain hydrologic and hydraulic models of the District's reservoirs and the locks and dams. When the Mississippi River portion of CWMS becomes deployed and operational, the functionality of the MBMS model will be replaced. Rather than using UNET, CWMS will use a HEC-RAS unsteady flow model. The sharing of data with the NWS will remain unchanged.

b. Roles of Other Agencies. The National Weather Service (NWS) electronically provides the District forecasted stage hydrographs of the major tributaries to the Mississippi River by 0830-hours daily. Water Control Section inputs these hydrographs into the Mississippi Basin River System model and makes a run. The model converts the stage-hydrographs to discharge-hydrographs and routes the flow. The results are electronically transferred to the NWS River Forecast Center in Chanhassen, Minnesota by 0930-hours. The NWS uses the UNET results and the results from their Mississippi River forecast model to provide stage forecasts at various points along the Mississippi River.

6-02. Flood Condition Forecasts. Since 1997, St. Paul District has been using the Mississippi Basin Modeling System (MBMS) to forecast flood conditions at Lock and Dam No. 3. The system utilizes UNET, which is an unsteady flow computer program. UNET was modified to simulate navigation dams according to operating rules. While the program allows the operating rules to vary according to the season, it does not account for gate operation. Therefore, model results are limited while the dam is in a regulated condition. Flow and stage data are required to provide the boundary conditions that drive the model. Observed stages are updated daily. The model is dependent upon forecasted tributary inflow. The

National Weather Service (NWS) electronically mails the five-day forecasted stage-hydrograph for the major tributaries to Water Control by 0830-hours daily. The hydrographs typically include the 24-hour quantitative precipitation forecast (QPF). Water Control extrapolates the tributary stage-hydrographs to 30-days. Forecasts beyond 5-7 days are very approximate due to unknowns such as additional rainfall. Therefore, only the five-day forecast for the locks and dams is made available to the public via the Water Control web site; *www.mvp-wc.usace.army.mil*. The 30-day forecast is available to Corps personnel through the Intranet.

6-03. Long-Range Forecasts. The Mississippi Basin Modeling System (MBMS) is used for making long-range forecasts. It is run everyday at about 0930-hours. The model forecasts elevation and discharge for the locks and dams and control points 30-days out. However, as previously noted, the five-day tributary inflow provided by the National Weather Service only includes the 24-hour quantitative precipitation forecast (QPF). Therefore, judgment is required when looking at long-range forecasts.

6-04. Drought Forecast. The lock and dam system operates as “run of the river”. That is what ever flow enters the pool is passed on. During low flow, the project pool elevation is maintained provided there is sufficient inflow to meet withdrawal needs and pool evaporation. There is no drought forecasting model other than the Mississippi Basin Modeling System previously discussed.

VII - WATER CONTROL PLAN

7-01. General Objectives. The general objective of the water control plan is to maintain a minimum depth of nine feet along the navigation channel of Pool No. 3, without inducing higher stages during flood events. Project pool elevation for Lock and Dam No. 3 is 675.0 ± 0.2 feet (1912 adjustment). The control point for this elevation was established near the intersection of the ordinary high water line and the project pool elevation. For Pool No. 3, the "primary control point" is located on the left bank of the Mississippi River near the confluence with the St. Croix River at Prescott, Wisconsin (see **Figure 5-1**). Maintaining project pool elevation at this location during periods of low flow ensures a minimum channel depth of nine feet, supplemented with periodic dredging.

The dam has minor localized impacts during flood events. The required spillway area at the dam was designed such that when all the gates are out of the water, the swellhead produced by the piers is less than one foot. Long before flood stage is reached, all the gates are raised above the water surface so that natural open river conditions exist during the flood period.

7-02. Constraints.

a. Pool Levels. For low discharges, the pool is maintained at elevation 675.0 ± 0.2 feet (1912 adjustment) at the primary control point located at Prescott, Wisconsin. This is "project pool" or "normal pool" for Lock and Dam No. 3 and was mandated by the 79th Congress (1st Session, House Document No. 137, 9 December 1931). As discharges increase, there is a "drawdown" in the water surface elevation at the dam. The drawdown elevation is based on necessary navigation depths upstream of the dam. Drawdown at the dam was first established at 2.0 feet below project pool level. Over dredging of problem areas stopped in 1970. Therefore, due to the adverse effects on navigation, riverfront property, and conservation interests, drawdown was reduced to 1.0 foot in 1971. Drawdown at the dam is constrained to elevation 674.0 ± 0.2 feet.

b. **Maximum Outflow Velocity.** Maximum outflow velocities are limited due to the scour protection downstream. The original design plan set maximum outflow velocities at 4.5 feet per second for standard operating procedures with an allowance to go to 6.0 feet per second for an emergency situation. In 1983, additional riprap was placed upstream and downstream of the dam. Since this time, routine maximum gate openings have been computed based on a maximum outflow velocity of 6.0 feet per second. The design velocity of 6.0 feet per second may be exceeded for short periods of time (15 to 20 minutes) during emergency operations (e.g., barge incident, passing of debris).

c. **Open River Conditions.** The dam is "out of control" when the gates are raised clear of the water surface and "open river conditions" exist. This typically happens when the differential head is less than one foot and the discharge is around 36,000 cfs. When the roller gates are put back in the water, the total gate opening is 56 feet.

d. **Closure of the Lock to Navigation.** Prior to 1988, the lock would close to navigation when high water dictated the removal of the miter gate motors. This occurred when the upper pool reached elevation 681.0 feet (1912 adjustment). As part of the major rehabilitation work in 1988, the motors were raised; therefore, the lock can now technically remain open to navigation provided water is not spilling over the upper miter gates of the main lock at elevation 683.0 feet. While this is the physical constraint, closure will often happen before the water level gets this high due to wave action over the miter gates. In addition, it is not unusual for the Coast Guard to close the river to navigation before this elevation is reached.

The lock is also closed when ice is too thick to permit tow traffic. As winter approaches, the lock remains open as long as towboats and barges can travel. Water temperatures are monitored to predict lock closure. When temperatures approach the low 30's, ice can form overnight and can impact the entire pool.

In early March, the ice often becomes thin enough for some tow traffic and the lock is opened. The ice thickness on Lake Pepin (Pool No. 4) is monitored weekly. When the ice is down to about six inches of blue ice, tow traffic can soon be expected. **Table 7-1** shows some of the recent history of opening and closing dates for Lock and Dam No. 3.

Table 7-1
Spring Opening and Fall Closing Dates

Year	Opening Date	Closing Date	Year	Opening Date	Closing Date
1972	24-Mar	06-Dec	**1988**	21-Mar	29-Nov
1973	18-Mar	06-Dec	**1989**	31-Mar	23-Nov
1974	15-Mar	11-Dec	**1990**	18-Mar	28-Nov
1975	05-Mar	14-Dec	**1991**	22-Mar	23-Nov
1976	04-Mar	05-Dec	**1992**	09-Mar	01-Dec
1977	19-Mar	05-Dec	**1993**	22-Mar	29-Nov
1978	04-Apr	30-Nov	**1994**	25-Mar	29-Nov
1979	31-Mar	04-Dec	**1995**	15-Mar	28-Nov
1980	27-Mar	04-Dec	**1996**	19-Mar	25-Nov
1981	08-Mar	03-Dec	**1997**	28-Mar	24-Nov
1982	24-Mar	07-Dec	**1998**	11-Mar	16-Dec
1983	04-Mar	04-Dec	**1999**	19-Mar	09-Dec
1984	04-Mar	30-Nov	**2000**	04-Mar	01-Dec
1985	18-Mar	30-Nov	**2001**	04-Mar	30-Nov
1986	22-Mar	05-Dec	**2002**	15-Mar	27-Nov
1987	09-Mar	28-Nov	**2003**	30-Mar	29-Nov

e. Maximum Number of Gates Closed. At times it is necessary to close one or more gates for maintenance purposes (e.g. painting). All gate closures shall be coordinated with the river regulation desk at Water Control. The maximum number of gates allowed to be closed will be at the discretion of Water Control based on conditions, as they exist. The following table was prepared based on outlet velocities of 4.5 feet per second.

Table 7-2
Maximum Number of Gates Allowed to be Closed

Flow (cfs)	No. of Roller Gates Closed
Below 6,000	3
6,000 – 13,000	2
13,000 – 22,000	1
Above 22,000	0

7-03. Overall Plan for Water Control.

a. General Plan. The navigation channel of Pool No. 3 is 300 feet wide along the straight reaches of the river and varies from 300 feet to 550 feet in the bends. The primary purpose of Lock and Dam No. 3, combined with periodic dredging, is to maintain a minimum depth of nine feet throughout the navigation channel without inducing higher stages during flood events. During flows of less than 5,000 cfs, the pool is fairly flat. To meet depth requirements in the upper pool requires the pool elevation at the "primary control point" (Prescott, Wisconsin) to be at elevation 675.0 feet (1912 adjustment). Because it is not possible to maintain an exact elevation, there is a two-tenths of a foot tolerance. Therefore, "project pool" elevation for Lock and Dam No. 3 is 675.0 ± 0.2 feet at Prescott, Wisconsin. As discharges increase, gates are opened at the dam to maintain project pool at the primary control point. This results in a drawdown in the water surface elevation at the dam. Maximum allowable drawdown is one foot below project pool level or elevation 674.0 ± 0.2 feet. When the water surface at the dam is lowered to its maximum drawdown elevation, control switches to the dam and the lock and dam is now in "secondary control." As discharges continue to rise, gates are opened to maintain secondary control. When discharges get up to around 36,000 cfs, the differential head is reduced to less than one foot and it is no longer possible to maintain secondary control. At this time, the gates are raised above the water surface and the dam is said to be in "open river conditions". On the recession limb of the hydrograph, the gates are put back into the water, maintaining secondary control, and as flow continues to decrease, control passes from secondary to primary. The operating curves shown on **Plate 7-1** were updated based on historical flow data. The following table summarizes the control conditions at the lock and dam.

Table 7-3
Control Conditions at Lock and Dam No. 3

Control Conditions	Approximate Discharge	Control Point Gage Elevation	Lock and Dam 3 Pool Elevation
Primary	< 5,000 cfs	675.0 ft	≤ 675.0 ft
Primary to Secondary	5,000 to 15,000 cfs	> 675.0 ft	< 675.0 ft > 674.0 ft
Secondary	15,000 to 36,000 cfs	> 675.0 ft	674.0 ft
Open-River	> 36,000 cfs	> 675.0 ft	> 674.0 ft

b. Computed Discharge. Flows through the dam are computed based on the differential head and the gate settings. At high discharges when the gates are out of the water, discharges are computed based on the tailwater-rating curve. Discharges are computed as part of the "River Program." To prevent a discontinuity from computed outflows and the tailwater-rating curve, computed outflows are transitioned to the tailwater rating.

Discharge ratings for the gates were originally developed based on laboratory tests on a hydraulic model. A Gate Regulation Schedule was developed based on gate discharge, maximum outflow velocity of 4.5 feet per second, and an effort to equally distribute flow across the dam. In 1973, the US Geological Survey measured outflows in the prototype. This resulted in a new relationship in the per foot discharge for the roller gates (see **Plate 7-3**). The analysis also showed a slight change in the tailwater rating. These changes were presented in a new Gate Regulation Schedule (revised 1973). Included with the change in per foot discharge, was a reevaluation of the flow distribution across the dam. Flow was now to be distributed based on balancing outflow velocities. This schedule remained unchanged until 1983 when riprap was placed upstream and downstream of the dam. Based on this, the maximum outflow velocity was raised to 6.0 feet per second and hence the maximum gate openings were changed on the Gate Regulation Schedule to reflect this.

As part of the current updates to this manual, the Operating Curves (**Plate 7-1**) were updated using recent data. The data indicate a slight shift in the pool and tailwater-rating curves at higher flows. To complete the update of the Gate Regulation Schedule the maximum allowable gate openings were revised. Maximum allowable gate openings are based on the flow velocity over the end sill. For example, consider a discharge of 22,000 cfs and a differential head of 3.80 feet with a tailwater elevation of 670.20 feet. Based on $Q = VA$, where Q is the discharge per foot, times the maximum allowable gate opening, V is the maximum allowable flow velocity of 6.0 feet per second, and A is the flow area over the end sill for one gate, the following maximum allowable gate opening was determined. Note that flow area is computed by [(gate width + one pier width) x (tailwater elevation – end sill elevation)].

<u>Roller Gate</u>
$Q = VA$
1050 cfs/ft (max gate opening) = 6.0 fps (80 ft + 15 ft) (670.20 ft – 652.50 ft)
Max Gate Opening = 9.6 ft

Table 7-4 shows the new Gate Regulation Schedule.

Table 7-4
Gate Regulation Schedule
4 Roller Gates

Total Discharge cfs	Total Gate Opening in Feet Rollers	Elevation in Feet 1912 Adjustment Pool	TW	Head In Feet	Discharge (cfs) per Foot of Opening Rollers	Discharge (cfs) Rollers	Max Allowable Opening of a Gate Rollers
4,000	2.5	674.90	667.35	7.55	1555	3,888	5.4
5,000	3.5	674.86	667.45	7.41	1538	5,383	5.5
6,000	4.0	674.80	667.55	7.25	1518	6,072	5.7
7,000	4.5	674.77	667.65	7.12	1502	6,759	5.7
8,000	5.5	674.70	667.75	6.95	1482	8,151	5.9
9,000	6.0	674.63	667.88	6.75	1457	8,742	6.0
10,000	7.0	674.55	668.00	6.55	1432	10,024	6.2
11,000	8.0	674.45	668.15	6.30	1399	11,192	6.4
12,000	9.0	674.32	668.30	6.02	1361	12,249	6.6
13,000	10.0	674.20	668.40	5.80	1332	13,320	6.8
14,000	11.0	674.10	668.58	5.52	1294	14,234	7.1
15,000	12.0	674.00	668.75	5.25	1258	15,096	7.4
16,000	13.0	674.00	668.95	5.05	1230	15,990	7.6
17,000	14.0	674.00	669.10	4.90	1209	16,926	7.8
18,000	15.5	674.00	669.30	4.70	1180	18,290	8.1
19,000	16.5	674.00	669.50	4.50	1151	18,992	8.4
20,000	18.0	674.00	669.70	4.30	1123	20,214	8.7
21,000	19.5	674.00	669.95	4.05	1087	21,197	9.2
22,000	21.0	674.00	670.20	3.80	1050	22,050	9.6
23,000	22.5	674.00	670.40	3.60	1019	22,928	10.0
24,000	24.5	674.00	670.65	3.35	981	24,035	10.5
25,000	26.5	674.00	670.90	3.10	944	25,016	11.1
26,000	28.5	674.00	671.10	2.90	913	26,021	11.6

Table 7-4 - Continued Gate Regulation Schedule 4 Roller Gates							
Total Discharge cfs	Total Gate Opening in Feet Rollers	Elevation in Feet 1912 Adjustment		Head In Feet	Discharge (cfs) per Foot of Opening Rollers	Discharge (cfs) Rollers	Max Allowable Opening of a Gate Rollers
		Pool	TW				
27,000	30.5	674.00	671.30	2.70	883	26,932	12.1
28,000	33.0	674.00	671.50	2.50	853	28,149	12.7
29,000	35.5	674.00	671.75	2.25	816	28,968	13.4
30,000	39.0	674.00	672.05	1.95	771	30,069	14.5
31,000	42.5	674.00	672.30	1.70	733	31,153	15.4
32,000	46.0	674.00	672.55	1.45	695	31,970	16.4
33,000	50.0	674.00	672.78	1.22	659	32,950	17.5
34,000	54.5	674.00	673.00	1.00	624	34,008	18.7
35,000	59.0	674.00	673.20	0.80	592	34,928	19.9
36,000	Out of Control – Gates Clear of Water. Put gates back in at 56 ft Roller Gates.						

c. **Regulation Procedure.** Each morning at 0630-hours, the Water Control manager prints the Regulation Sheets containing all the input from the lock and dam sites. The Regulation Sheet contains the past 24-hours of accumulated data (**Table 7-5**). Regulation for Lock and Dam No. 3 begins at Lock and Dam No. 2. Gate changes at Lock and Dam No. 2 directly influence action needed at Dam No. 3. After regulating Lock and Dam 2, inflow to Pool No. 3 is determined. Inflow consists of outflow from Lock and Dam No. 2, inflow from the St. Croix River and any miscellaneous inflow. Outflow from Lock and Dam No. 2 is computed as part of the daily regulation. This discharge must be adjusted by any gate change given that morning for Lock and Dam No. 2. The St. Croix River inflow is the sum of the outflow from the Xcel Energy Dam at St. Croix Falls, Wisconsin and the Apple River Falls Dam near Somerset, Wisconsin (**Plate 5-1**), lagged approximately one day to allow for travel time. The facility operators at these sites enter the hydropower flow data by means of a secure computer connection to the District's Water Control computer. The 24-hour average discharge at each location is entered at 1600-hours each day, thus allowing for an appropriate lag time. The 24-hour change in total discharge is noted. Miscellaneous inflow will vary seasonally but for simplicity it is assumed to be a constant 200 cfs. This may be modified if precipitation has occurred in the last 24 hours. As a general rule, for each inch of rainfall that has fallen in past 24 hours, an additional 900 cfs is added to the miscellaneous inflow. Inflow is totaled and the 24-hour change is noted. Also noted are the change in outflow and any gate changes made in the past 24 hours. Next, the rate of fall or rise of the pool is calculated. This is done at the dam, the control point, and at Stillwater. Note all 24-hour changes. Allow for wind at the dam. That is, adjust the pool elevation, up or down, 0.1 foot per 10 mph of wind (see **Section 4-04**). Determine if the pool is in primary or secondary control. Estimate the needed change in discharge to maintain the proper pool band. To aid in this assessment, it has been determined that a change in outflow of 900 cfs over a 24-hr period of time will result in about a one-tenth of a foot change in the overall pool elevation. This value was computed based on the effective project pool area of 17,950 acres.

Once the needed change in discharge is determined, the Gate Regulation Schedule is used to distribute flow and hence set gate changes. The gate change information is e-mailed to the lock site and the St. Paul District's intranet at approximately 0800-hours each day. The orders are typically one of four types; (1) no change, (2) no change at present, (3) open a given amount, or (4) cut a given amount. A "no change at present" order is followed by an "if statement". For example, "if the pool falls to elevation 674.8 feet, cut 2 feet." All "open" and "cut" orders include the anticipated gate change impact on flow. All four types of orders are followed by a "pool band" to be maintained at the dam. For example, "hold 675.0 ± 0.2 feet". As a final note, the orders may also include "allow for wind on the high side" or "allow for wind on the low side", if appropriate. Sometimes it is necessary to check back with the lock site in the afternoon. If this were the case, the site would be informed, via the morning's orders, that Water Control will be contacting them at a given time (typically 1400-hours). At that time, site personnel would provide present and noon pool and tailwater elevations, and present wind conditions. Water Control would then provide any gate change verbally over the telephone or via e-mail. **Table 7-5** is a portion of the Regulation Sheet displaying data for Lock and Dam No. 3. The portion printed in black represents the daily regulation sheet as printed at 0630-hours while that printed in blue represents the morning's regulation notes. If additional regulation is needed later in the day, a different color is typically used for making notes.

Table 7-5
Regulation of Lock and Dam No. 3 for 27 July 2003

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Outflow from LD 2: 12,700 cfs
Orders to LD 2: Cut 1-foot, dec flow 700 cfs to 12,000 cfs
Note:  There was a 2-foot cut (1400 cfs) between 2400 and 0400-hrs.

                                         4-RG    [primary = 675.00
gates in/out:  56'  @ 36,000             Total   for flow < 15,000]
               | sec: |                 Roller                CP-3
LOCK 3         |674.00|  Tail    Flow    Gate   Stillwater   Prescott
          ----------------------------------     TM3          TM3
20SEP02 0800   674.12  670.05  21700   20.0    676.45       676.15
        1200   674.12  670.00  21800   20.0
        1600   674.11  669.97  21900   20.0
        2000   674.09  669.94  21900   20.0    No gate changes.
        2400   674.08  669.90  22000   20.0
21SEP02 0400   674.06  669.87  22100   20.0
        0630   674.05  669.87  22000   20.0    676.27       676.04
           down 0.08         up 300       down 0.18    down 0.11
                                            Apple River    462
phone   HEAD     4.2                        St Croix +    3822
##025   Q/foot   1101                       (from NSP)   -------
        temp.        55                                   4284 steady
        precip.    0.01
        wind (dir&speed) 315 @ 10 Pool up 0.1 ft due to wind.
        INFLOW:
          L/D 2      -    12000
          St. Croix -    4300          Orders:
          900 CFS   -                  Cut 2.0 ft
          Misc.     -     200          Dec. flow 2,000 to 20,000 cfs
                        ------         Hold 674.00 ± 0.2 ft
                         16,500        AFW H.S.
                     down 2,100
```

The following steps walk through the regulation procedure for this particular day. This is intended only as an example.

Step 1. Determine inflow to Pool 3.
Computed outflow from LD 2 was 12,700 cfs.
LD 2 orders were to cut 700 cfs.
St. Croix River inflow is 4,300 cfs.
Miscellaneous inflow is 200 cfs.
Rainfall was 0.01 inch (insignificant)
Total Inflow = 12,700 – 700 + 4,300 + 200 = 16,500 cfs
(down 2,100 cfs from yesterday).

Step 2. Note change in outflow.
Up 300 cfs due to change in head.

Step 3. Note change in pool elevation.
Down 0.11 ft at Prescott; Down 0.18 ft at Stillwater.
Wind is 10 mph (north); 0.08 + 0.10 = 0.18 ft down at the dam.

Step 4. Primary or Secondary Control?
Flow is greater than 15,000 cfs; therefore, Secondary Control.
For Secondary Control, maintain 674.00 ± 0.2 ft at the dam.

Step 5. Estimate needed change in discharge.
Inflow is down 2,100 cfs from yesterday.
Total cut in outflow at LD 2 was 1,400 + 700 = 2,100 cfs
Pool is down about 0.15 feet but is about in mid-band.
Needed Change in Outflow: "match decrease in inflow"
"Decrease Outflow by 2,100 cfs"

Step 6. Set gate change.
A one-foot cut would decrease outflow ~1000 cfs.
"Cut 2.0 ft. Decrease flow 2,000 to 20,000 cfs."

Step 7. Set the pool band.
We are in Secondary Control; therefore,
"Hold elevation 674.00 ± 0.2 feet."
"Allow for wind on the high side."

d. Winter Regulation. Before freeze-up and when river discharges allow, all four roller gates are placed in the "submerged position". When the bottom of the gate is at the gate sill (elevation 655.0 ft), the top of the gate is at elevation 675.0 feet. As the gate is lowered from this position, the bottom of the gate rotates along the curved surface downstream of the end sill (**Plate 2-2**, Section B-B) and thereby allows flow over the top of the gate and no flow beneath the gate. The roller gates can be submerged up to five feet below normal pool elevation. Discharge curves over a submerged gate were developed in the original physical model. The data set was later put into tabular form as presented in **Table 7-6**. The gates are never submerged less than one foot because of problems with passing ice. The rating curves were incorporated into the Regulation Program such that lock personnel enter the total gate opening on a four-hour intervals and the program computes the discharge. Total flow is distributed over the four gates with no more than a one-foot difference in gate opening. At times the discharge capacity of the submerged roller gates may be inadequate in the event of winter thaws or rains and it may become necessary to raise one or more of the roller gates into the normal position. The roller gates are equipped with electric drum and side seal heaters, but if the roller gates are submerged one foot or less, some steaming and chopping may be necessary before the roller gates can be moved.

Table 7-6 Discharge Through Submerged Roller Gate – cfs										
Pool Elevation	Head Feet	Depth of Submerged Gate								
		1.0 ft	1.5 ft	2.0 ft	2.5 ft	3.0 ft	3.5 ft	4.0 ft	4.5 ft	5.0 ft
675.2	8.0	880	1110	1390	1710	2070	2450	2870	-	-
	7.0	850	1080	1360	1680	2040	2420	2840	-	-
675.1	8.0	840	1050	1330	1640	1990	2370	2780	-	-
	7.0	810	1020	1300	1610	1960	2340	2750	-	-
675.0	8.0	800	1010	1270	1570	1910	2300	2690	3110	-
	7.0	770	980	1240	1540	1880	2270	2660	3080	-
674.9	8.0	770	970	1210	1510	1850	2220	2610	3040	-
	7.0	740	940	1180	1480	1820	2190	2580	3010	-
674.8	8.0	740	920	1160	1450	1770	2140	2520	2950	-
	7.0	710	890	1130	1420	1740	2110	2490	2920	-
674.7	7.0	680	850	1080	1360	1680	2040	2420	2840	-
	6.0	650	820	1050	1330	1640	2000	2390	2810	-
674.6	7.0	650	810	1020	1300	1610	1960	2340	2750	-
	6.0	620	780	990	1270	1580	1630	2310	2720	-
674.5	7.0	620	770	980	1240	1540	1880	2270	2660	3080
	6.0	590	740	940	1210	1510	1850	2240	2630	3050
674.4	7.0	600	740	940	1180	1480	1820	2190	2580	3010
	6.0	560	700	900	1150	1440	1780	2160	2540	2980
674.3	6.0	540	680	860	1100	1380	1710	2070	2460	2890
	5.0	500	640	810	1060	1350	1660	2030	2420	2850
674.2	6.0	520	650	820	1050	1330	1640	2010	2390	2810
	5.0	480	610	780	1010	1280	1600	1960	2350	2770
674.1	6.0	500	620	780	990	1270	1580	1930	2310	2720
	5.0	460	580	740	950	1220	1540	1890	2270	2680
674.0	6.0	480	580	740	940	1210	1510	1850	2240	2630
	5.0	440	550	700	900	1170	1470	1810	2200	2590
674.0	4.0	390	500	650	860	1120	1420	1760	2150	2540
	3.0	340	450	600	800	1060	1370	1700	2100	2480
674.0	2.0	280	380	540	740	1000	1300	1640	2030	2420
	1.0	200	310	460	670	920	1230	1570	1960	2350
673.9	6.0	-	560	700	900	1130	1440	1780	2160	2550
	5.0	-	520	670	860	1110	1410	1740	2120	2510
673.8	5.0	-	-	630	820	1060	1350	1660	2030	2420
	4.0	-	-	590	770	1010	1300	1620	1990	2370
673.7	4.0	-	-	-	730	960	1240	1560	1920	2300
	3.0	-	-	-	680	910	1180	1500	1860	2250

Throughout the winter, the tainter valves in the lock walls are kept open two to four feet each to prevent the formation of a solid sheet of ice in the lock chamber. Tainter valve openings are entered at the site along with all other daily data entries. The River Program calculates the total discharge based on the rating table shown in **Table 7-7**.

Table 7-7 Discharge Through Lock Tainter Valve - cfs					
Head in Feet	Discharge per Foot Opening	Head in Feet	Discharge Per Foot Opening	Head in Feet	Discharge Per Foot Opening
0.5	30	3.5	95	6.5	128
1.0	50	4.0	100	7.0	131
1.5	62	4.5	106	7.5	138
2.0	74	5.0	111	8.0	140
2.5	81	5.5	118		
3.0	89	6.0	122		

During the non-navigation season, on the weekends and holidays, shifts are limited to one person at the dam site. Presently shifts are 12-hours in length with no overlap. For safety purposes, two people are required to be on duty for a gate change. Therefore, when a gate change is required overtime will be paid. Water Control makes an effort to get orders out by 0730-hours to minimize the required overtime.

Due to the limited staff at the site and the difficulty in moving the submerged roller gates, the tolerance for stage deviation is increased to plus or minus three-tenths of a foot. That is, the control point at Prescott, Wisconsin is to be maintained at elevation 675.0 ± 0.3 feet (1912 adjustment). Because of the added benefit to fish habitat, Water Control makes an effort to operate on the high side of the band during winter months to reduce oxygen depletion in the backwater areas. Therefore, the target for primary control during the winter months is between elevation 675.0 feet and 675.3 feet.

7-04. Standing Instructions to Lock and Dam No. 3 Staff. Site personnel are to report all data collection to Water Control via a remote computer using the program “sig-na-term”. The data entry interval varies from once a day to every four hours. Four-hour data begin at 0400-hours, eight-hour data and daily data begin at 0800-hours. However, note that all 0800-hour data is actually taken at 0600-hours. Four-hour data include pool and tailwater elevations, gate settings, and tainter valve settings (during the winter). Eight-hour data includes wind speed and direction and air temperature. Daily data includes precipitation, max and min air temperature, water temperature, and the water surface elevations at Prescott and Stillwater. During the winter months, percent of ice coverage over the upper pool and lower tailwater, ice thickness, snow depth, and snow-water equivalent are recorded once a week on Sundays.

Lock and dam personnel also maintain an Operating Log Book that includes all the data input to “sig-na-term” plus any notes concerning the day's activities. The Stevens PAV-C strip charts are to be mailed to Water Control every year.

At 0645-hours everyday, the Water Control regulator analyzes the field data and at around 0800-hours, the daily orders for gate movements are sent to the site via e-mail. On weekends and holidays during the winter operations, orders are sent by 0730-hours due to limited staffing at the dam site. Gate changes are then made as soon as possible. If Water Control has notified the site that they will contact them again later in the day, site personnel will have the noon and present pool and tailwater elevations as well as any other pertinent information (e.g. wind speed and direction) available at that time.

Normal duty hours for Water Control are 0630 to 1500-hours during the week, and 0630 to 0930-hours on weekends and holidays. During the course of non-duty hours site personnel may make gate changes as necessary to stay within the pool band prescribed. The site is limited however to changes up to ten percent of the 1600-hour discharge. If a gate change greater than this is necessary, site personnel should contact the river regulator at home. If the need for a gate change becomes necessary at 0400-hours, no gate change will be made. Water Control will provide the necessary gate change and band limit with the morning’s orders. The following is a list of Water Control personnel with river responsibilities. The first contact should be the person who issued the last orders. If that person is not available, contact should be made in the order listed in **Table 7-8**. The weekend pager number is 612-660-8053. Lock personnel contacting Water Control personnel during non-duty hours should have pool and tailwater readings, wind speed and direction, amount of precipitation since last report, latest discharge calculations, and all gate changes made since the morning gate change.

Table 7-8
Water Control Personnel Telephone Numbers

Name	Non-Duty	Office
Scott Bratten	651-436-6135	651-290-5624
Dennis Holme	651-483-4003	651-290-5614
Ted Pedersen	715-639-2625	651-290-5253
Farley Haase	715-235-1928	651-290-5633
Ferris Chamberlin	651-653-7981	651-290-5619
Robert Engelstad	651-459-6343	651-290-5610

If lock personnel have any questions regarding the Water Control order, they are to contact the river regulator via telephone (651-290-5624) and the question will be resolved. During computer outages, log sheets will be faxed to Water Control Section (651-290-5841) and orders will be given via telephone or FM radio.

In the event of a gate failure or any occurrence that will require the installation of the bulkheads, communications must be established as quickly as possible with Water Control Section and Construction and Operations (Con-Ops) Division. Under full head conditions at the dam, the force is too great to allow the installation of the bulkheads. Therefore, the operating head must be reduced. Water Control will coordinate gate movements with site personnel in preparation for installation and removal of the bulkheads.

7-05. Flood Control. Lock and Dam No. 3 has no flood control benefits. It is operated strictly for navigation. While it may seem possible that the pools be drawn down over the winter months to provide storage for spring runoff, this plan has no merit for two reasons. First, the Anti-Drawdown Law (Public Law 697) of June 1948 prevents the drawdown of the pools during the winter months. Secondly, the storage volume that would be made available in the pool is insignificant in comparison to the flood flow volume. The pool would be filled in a matter of hours and would have no impact on the peak flood stage.

7-06. Recreation. The major recreation features of Pool No. 3 are fishing, hunting, boating, and bird watching. Numerous people drive to the pool for wildlife viewing during the waterfowl migration. Construction of the lock and dam inundated the numerous wing dams that were constructed as part of the six-foot channel project. The wing dams as well as some of the backwater areas provide excellent fish and waterfowl habitat. As for recreational boats, there are typically around 17,000 boats locked through each year. In 2002 there was 16,740 recreation boats locked through in 4,034 lockages. **Table 7-9** shows a comparison of recreational boating to commercial traffic.

Table 7-9
Commercial & Recreational Lockages at Lock No. 3

Year	Commercial Lockages	Recreational Lockages	Other Lockages	Total Lockages	Percent Recreation
1991	1,481	3,825	168	5,474	70 %
1992	1,316	3,562	75	4,953	72 %
1993	957	2,805	145	3,907	72 %
1994	1,105	4,141	191	5,437	76 %
1995	1,157	4,031	377	5,565	72 %
1996	1,235	3,718	225	5,178	72 %
1997	1,154	3,601	175	4,930	73 %
1998	1,423	4,014	249	5,686	71 %
1999	1,461	3,763	338	5,562	68 %
2000	1,389	3,970	187	5,546	72 %
2001	1,341	3,413	230	4,984	68 %
2002	1,735	4,034	355	6,124	66 %

7-07. Water Quality. The Corps of Engineers does not perform any water quality analysis in Pool No. 3. However, as an element of the Environmental Management Program (EMP), the Corps of Engineers oversees the Long Term Resource Monitoring Program (LTRMP) of the Upper Mississippi River System. The LTRMP was implemented to provide decision makers with the information needed to maintain the Upper Mississippi River System as a viable multiple-use large river ecosystem. The LTRMP is being implemented by the US Geological Survey (USGS) in cooperation with the states of Illinois, Iowa, Minnesota, Missouri and Wisconsin with guidance and overall program responsibility by the Corps of Engineers.

7-08. Fish and Wildlife. Because the lock and dam was constructed for the purpose of navigation, the pool would sometimes be drawn down in non-navigation season. The 1934 "Anti-Drawdown" Act, as amended in 1948, prevented any winter drawdown of the pool. The pool is to be regulated the same as during navigation season. A higher stage in the backwater areas reduces the oxygen depletion; therefore, Water Control typically operates on the high side of the band during the winter months.

7-09. Water Supply. The cities, towns and villages along Pool No. 3 obtain their water from wells. Pool No. 3 does not provide a drinking water supply. However, both the Prairie Island and Allen King Power Plants extract water from the Mississippi and St. Croix Rivers, respectively for use as a coolant. The power plants are forced to shut down if the pool falls below elevation 671.0 feet (1912 adjustment).

7-10. Hydroelectric Power. There is no hydroelectric power at Lock and Dam No. 3.

7-11. Navigation. The primary purpose of Lock and Dam No. 3 is to provide navigation. The lock is 110 feet wide and 600 feet long. In a single lockage, this will accommodate a towboat (about the same length as a barge) and two rows of three barges (typically 35 ft by 195 ft). On a rare occasion a double-lockage can consist of the maximum of 17 barges (five rows of three with an empty hip barge on each side of the tow). Over the years tows have become wider such they have become wider than a barge. Therefore, it is a 16-barge tow that is now considered to be the maximum (five rows of three with one empty hip barge). The typical maximum however, is 15 barges. The first nine barges (three rows of three) enter the lock chamber and are broken free of the remainder. The haulage unit moves these through the lock and they are then tied to the guidewall. The towboat with the remaining six barges (two rows of three) passes through the lock and is rejoined with the nine other barges. Filling and emptying time for the lock under normal conditions is ten minutes. Lockage time for a single lockage is about 30 minutes. Time for a double lockage depends on the experience of the deck hands breaking and making couplings, number of loaded and empty barges, wind speed and direction, flow conditions, and whether it is an up bound or down bound tow. A down bound tow will take longer due to outdraft conditions at the dam. On average, a double lockage takes about 1 hour and 30 minutes.

7-12. Emergency Action Plans. The Emergency Action Plan is a stand-alone document entitled *Emergency Plan for Lock and Dam 3, Red Wing, Minnesota*, July 1985. The plan addresses emergencies related to above normal reservoir water levels and/or rapid release of large volumes of water past the dam. It covers identification of impending or existing emergencies and notification of other parties concerning impending or existing emergencies. Potential causes of an emergency affecting the operation or safety of Lock and Dam No. 3 include excessive seepage, sabotage, failure due to mechanical breakdown, extreme storm, failure of earth dikes or embankments, and failure due to navigation accident.

There are several protective measures taken at Lock and Dam No. 3 when a flood occurs. When the pool level is forecasted to go above elevation 677.0 feet (1912 adjustment), drain plugs are installed in the control building. As the pool rises, other actions are required. The following table a brief summary of the steps to be taken as water levels go higher. A more complete description of actions and duties are kept at the site.

Table 7-10
Flood Protection Measures

Pool Elevation	Action Taken
677.0 feet	Install miter gate drain plugs and install plug in control building basement wall drain.
678.0 feet	Fill underground fuel tanks and three LP tanks.
678.5 feet	Install warning flags or buoys on loading dock.
680.0 feet	Remove gate recess lighting from recess to hand railing.
681.0 feet	Remove miter gate over travel switches. Construct deflection dike on Spot Dike A. Remove auxiliary miter gate air compressors.
682.0 feet	De-energize electrical circuits for tunnel and miter gates.
683.0 feet	Close lock to navigation. Sandbag miter gate curtain walls and raise Spot Dike A. Turn off sewage pump. Pump out comfort station septic tanks and fill with water.
683.5 feet	Install stand pipe and drain plug in underground diesel fuel tank by control building.
684.0 feet	Remove gasoline in storage cabinet. Construct deflection dike from dam pier house to river wall. Remove above ground LP tank. Sand bag storage and pole buildings.
684.5 feet	Sand bag 400-foot section of access road.
685.0 feet	Remove electrical equipment from roadway gate openers. Remove tainter valve motors and limit switches. Remove auxiliary water pump motors and starters. Remove miter gate lighting. Sand bag control stand, fuel dispenser, pump house, transformer, and electrical panel. Protect tow haulage units. Remove hand railing from upstream miter gates. Remove gage equipment and protect gage house. Remove miter gate motors and brake assembly.
686.0 feet	Protect downstream control stand building.

7-13. Other. During a flood event, debris is passed beneath the gates as they are typically raised clear of the water. During ice breakup, ice is passed over the submerged roller gates.

7-14. Deviation from Normal Regulation. Project pool elevation is mandated by Congress. While in primary control, the pool is to be maintained at elevation 675.0 ± 0.2 feet (1912 adjustment) at the primary control point (Prescott, Wisconsin) as best as possible. Secondary control was established by the St. Paul District and was approved by the division office. Therefore, while in secondary control the pool at the dam is maintained at 674.0 ± 0.2 feet. The pool is not to be intentionally raised above or lowered below these elevations; however, temporary deviations are permitted. Because these deviations are unplanned and are only temporary, while actions are being taken to correct the situation, these exceptions do not require notification of the division office. Mississippi Valley Division (MVD) office must be notified when deviation outside the limits set by primary and secondary control is intentional and for a prolonged period of time. Planned deviations must be coordinated with MVD. A written request describing cause and effect will be sent to the Division Water Control Manager for approval. The District Commander or Chief of Engineering Division may deviate from the approved plan in an emergency situation. The District will inform MVD as soon as possible. This will include a written confirmation of the deviation and description of the cause.

7-15. Rate of Release Change. The only guideline for rate of release change is the "ten percent rule" (**Section 7-04**). During Water Control's non-duty hours, lock and dam personnel may only make a gate change to remain within the prescribed band such that it does not exceed 10 percent of the total flow. There are no other guidelines for rate of release change. Operation of the dam is basically run of the river. Therefore, rate of release change is nature driven.

VIII – EFFECT OF WATER CONTROL PLAN

8-01. General. The effect of the water control plan for Lock and Dam No. 3 is to maintain a nine-foot depth in the navigation channel of Pool No. 3. Lock and Dam No. 3 is just one piece of the lock and dam system that provides navigation from St. Louis, Missouri to Minneapolis, Minnesota. Navigation on the Upper Mississippi River progressed from a four-foot deep channel in 1866, to a four and one-half foot channel in 1878, to a six-foot channel in 1907, and finally, to a nine-foot channel in 1930's. A more complete description of this development is available in the Master Water Control Manual for the Locks and Dams.

8-02. Flood Control. The locks and dams provide no flood control benefits. They were constructed strictly for navigation purposes. The dam operates on a run-of-the-river principal. As discharge increases, the gates are opened. At around 36,000 cfs the gates are raised clear of the water surface. Therefore, for flood events, the only impact on the flow line is the swellhead at the dam, which is less than one foot.

8-03. Recreation. The project is not regulated for recreation purposes; however, it does provide recreational benefits. The three recreation qualities associated with Pool No. 3 are fishing, hunting, and boating. Project pool inundated the wing dams, constructed as part of the six-foot navigation project, and created backwater areas, which provide good fish and waterfowl habitat. While Lock and Dam No. 3 provides the necessary depths for the towing industry, it also is a benefit to recreational boating. The more stable water surface provides a more suitable environment for docks and marinas. There were over 4,000 recreation boat lockages in the year 2002.

8-04. Fish and Wildlife. The Minnesota Department of Natural Resources manages the Gore's Wildlife Management Area (WMA) in Pool No. 3 in accordance with Corps license agreement. The WMA includes nearly all of the pool except for the navigation channel and the Prairie Island Indian Reservation. The

Management Area was established to preserve a portion of the Upper Mississippi River for fish, migratory birds, other wildlife, and people.

8-05. Navigation. The Upper Mississippi River Nine-Foot Channel Project originated in the 1920's when it was promoted as a way to alleviate the Nation's worsening farm crisis. It was also aimed at allaying the inequities in commercial rail and water freight rates. The project was authorized by the Rivers and Harbors Act of 1930, with most of the locks and dams, including Lock No. 3, being constructed in the 1930's. The project was not without its controversy. For example, railroads claiming damage to their right-of-ways and conservationists fearing its effects on the environment. Ultimately, the economic benefits overrode all other concerns. After completion of the project, river traffic increased from 2,400,000 tons in 1939 to 68,400,000 in 1976. **Table 8-1** shows the recent history of tonnage commodities at Lock and Dam No. 3. In 1991 the product codes for tracking product types was changed. For more historical information concerning the Nine-Foot Channel Project, see the Master Water Control Manual for the Locks and Dams.

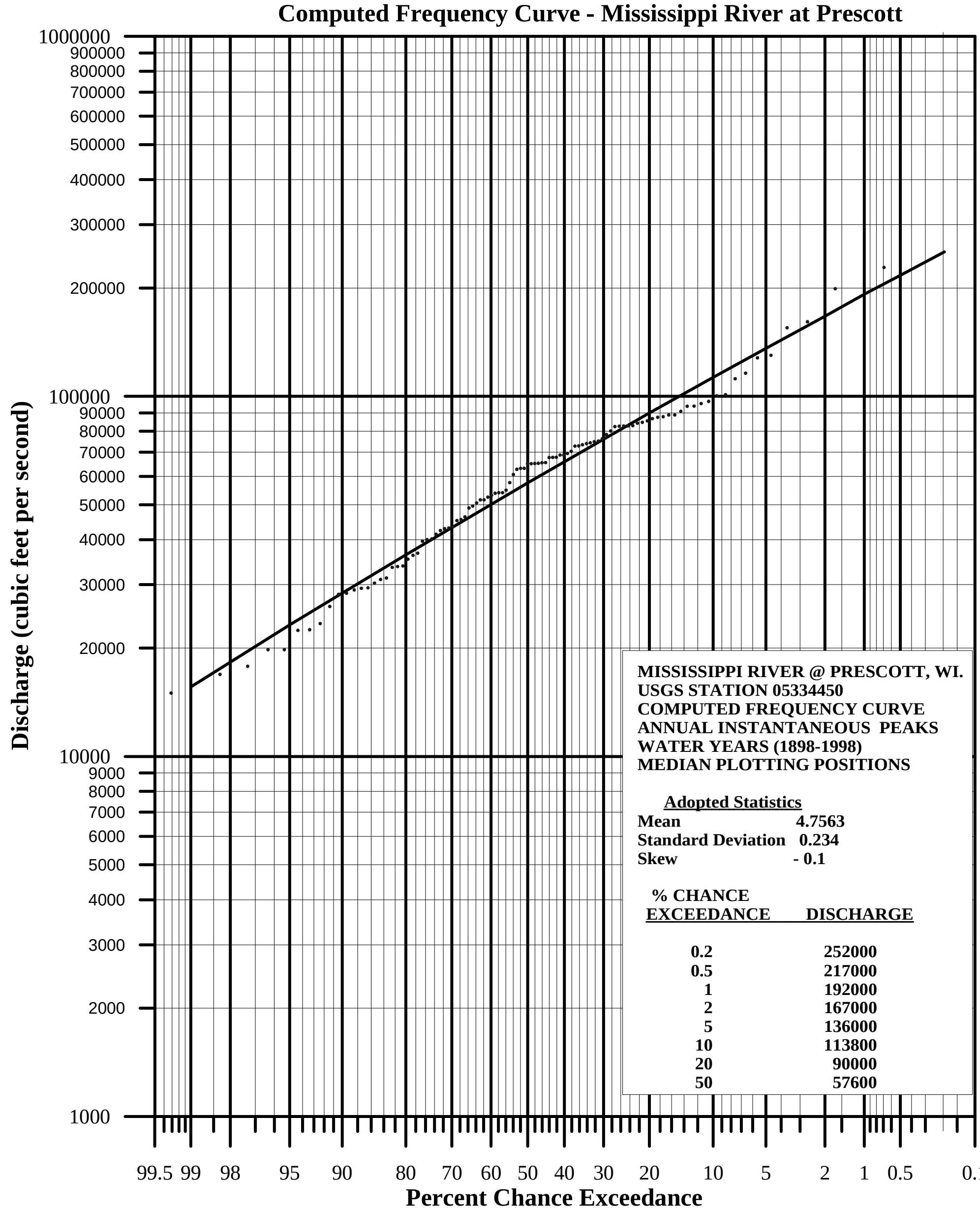
Table 8-1
Lock and Dam No. 3 Tonnage – Commodities

Year	Coal	Petrol Product	Chemical Products	Metallic Ores & Prod	Non Metallic Minerals	Stone Clay Cement	Farm Products	Misc Product	Total Tonnage
1980	1,756,000	1,570,000	824,000	176,000	256,000	147,000	7,555,000	167,000	12,451,000
1981	1,558,000	1,911,000	797,000	209,000	270,000	125,000	8,117,000	162,000	13,149,000
1982	1,553,000	1,100,000	894,000	82,000	283,000	147,000	8,077,000	109,000	12,245,000
1983	1,416,000	993,000	1,108,000	126,000	392,000	143,000	11,427,000	147,000	15,752,000
1984	994,000	993,000	1,454,000	104,000	461,000	184,000	9,846,000	192,000	14,228,000
1985	1,261,000	1,069,000	1,372,000	128,000	468,000	248,000	7,018,000	89,000	11,653,000
1986	1,191,000	776,000	1,458,000	146,000	498,000	227,000	5,541,000	93,000	9,930,000
1987	784,000	970,000	1,270,000	150,000	387,000	320,000	6,402,000	170,000	10,453,000
1988	1,127,000	1,005,000	1,214,000	125,000	439,000	366,000	7,139,000	167,000	11,582,000
1989	1,010,000	931,000	1,290,000	184,000	525,000	397,000	7,036,000	171,000	11,544,000
1990	1,267,000	1,265,000	1,280,000	250,000	555,000	484,000	8,951,000	124,000	14,176,000
Year	Coal	Petrol Prod	Chemical	Crude Materials	Manuf Goods	Farm Products	Equip Mach	Misc Products	Total Tonnage
1991	997,500	840,700	1,279,500	694,500	418,500	7,839,400	9,500	0	12,079,600
1992	758,900	298,000	1,728,500	785,100	461,400	8,731,200	14,000	9,500	12,786,600
1993	681,500	186,000	1,616,100	687,100	292,900	4,080,800	27,000	16,600	7,588,000
1994	730,200	262,000	2,111,600	781,400	409,300	4,976,800	3,000	53,200	9,324,500
1995	470,100	514,900	1,643,800	875,900	366,200	5,379,800	26,200	111,600	9,388,500
1996	559,900	439,900	1,651,700	859,000	235,900	6,473,700	16,000	63,000	10,299,400
1997	450,900	550,000	1,426,100	1,109,100	321,000	5,561,000	27,300	112,100	9,557,500
1998	544,500	884,300	1,575,600	979,600	521,400	5,965,000	14,300	58,800	10,543,500
1999	567,000	638,200	1,397,200	907,300	635,800	7,320,100	1,600	62,300	11,549,600
2000	545,329	602,554	1,663,485	884,179	553,986	6,409,948	15,100	191,074	10,865,655
2001	494,392	254,253	1,291,635	1,239,404	418,353	4,714,032	10,528	152,703	8,575,300
2002	338,100	397,117	1,481,946	1,292,798	621,228	6,235,694	17,900	207,163	10,591,946

8-06. Frequencies. St. Paul District developed a discharge-frequency relationship in 2002 for the control point at Prescott, Wisconsin. The Prescott gage is about 14.4 miles upstream of Lock and Dam No. 3. The frequency curve displayed in **Figure 8-1** represents peak flow relationships for the Mississippi River at Prescott. The frequency curve is derived from regionalized statistics for the mean and standard deviation, based on drainage area relationships at this location.

Figure 8-1.

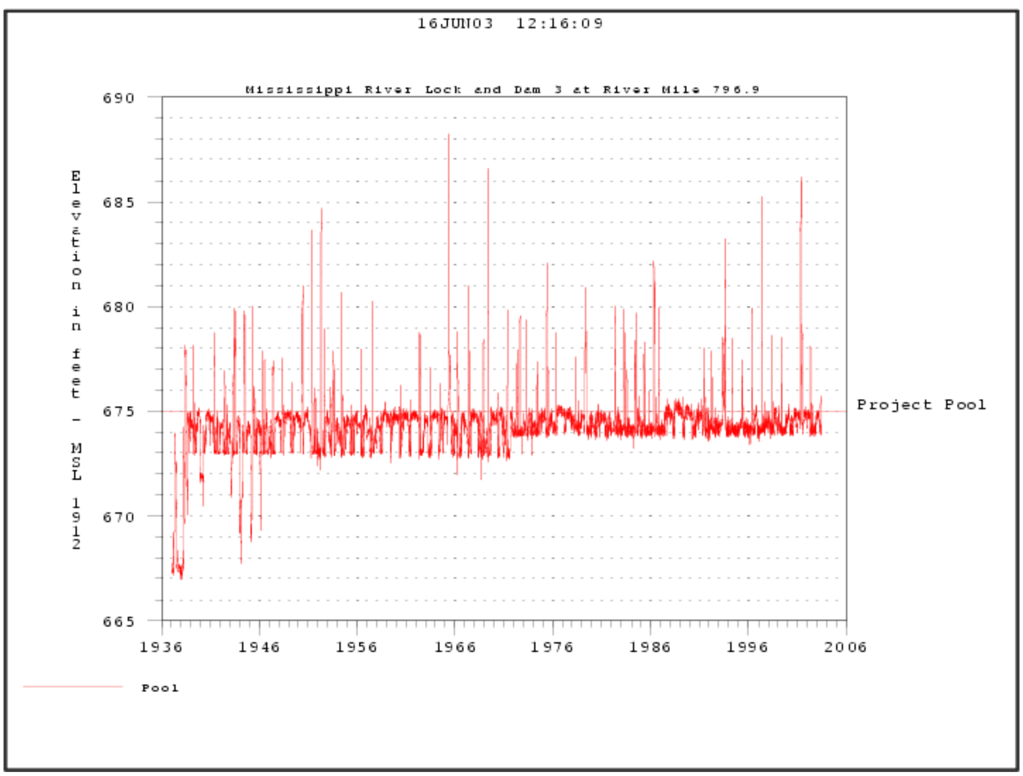
Computed Frequency Curve - Mississippi River at Prescott



Water surface profile frequencies were developed for Pools No. 2 through 10 in 1979 and again in 2003. The plots were broken into river reaches. Pool No. 3 is included with Pool No. 2. Along with the profile frequencies are plots of historic flood events for comparison purposes. The plot is shown **Exhibit E**.

Construction of the dam was completed in March 1938. By May, project pool elevation was achieved. The following shows a history of the pool elevation. The high elevations represent flood events and the lows represent drawdown at the dam (typically secondary control). When in secondary control, the pool elevation at the dam was allowed to be drawn down 2-feet below project pool level to elevation 673.0 feet (1912 adjustment) until 1971 when drawdown was reduced to elevation 674.0 feet. Prior to the Anti-Drawdown Law, passed by Congress in 1948, the pools were sometimes drawn down several feet below primary control elevation during the winter months. The greatest drawdown occurred in February 1944 when the pool was drawn down to elevation 667.69 feet.

Figure 8-2. History of Pool Elevation



IX – WATER CONTROL MANAGEMENT

9-01. Responsibilities and Organization.

a. Corps of Engineers. The Corps of Engineers is the owner, operator, and regulator for Lock and Dam No. 3. The St. Paul District, Water Control Section has direct day-to-day responsibility for gate adjustments at the dam. Construction and Operations Division is responsible for operation and maintenance of the lock and the dam. The following shows the working relationship for the locks and dams within the St. Paul District.

St. Paul District Office
← ← ← District Engineer → → →

↓	↓
Chief Engineering Division	**Chief Con-Ops Division**
↓	↓
Chief H&H Branch	**Chief Lock & Dam Project Office**
↓	↓
Chief Water Control Section	**Area Lockmaster**
↓	↓

Water Control Manager → → → → → Lockmaster

b. Other Federal Agencies. During high water, the National Weather Service (NWS) forecasts water surface elevations for the tailwater of Lock and Dam No. 3 (Red Wing). Water Control Section provides the NWS with the daily output from the Mississippi Basin Modeling System to aid them in making their forecast. The US Geological Survey (USGS) maintains the gage at Prescott, Wisconsin on the Mississippi River and the St. Croix Falls gage on the St. Croix River. Hourly stage values for these two gages can be obtained from the Water Control web site or from the USGS web site (Madison, Wisconsin), which is available by link from the Water Control web site at www.mvp-wc.usace.army.mil.

c. Private Organizations. The Diamond Bluff Associates, a private hunting club, owns the Gantenbein Lakes area on the Wisconsin side of Lock and Dam No. 3 (see **Figure 3-1**). While Corps owns the Spot Dike System along the left bank of the Mississippi River, Diamond Bluff Associates owns the Intermediate and Lower Dikes. These three low embankments connect the moveable dam to the Wisconsin shore and form two shallow floodplain lakes; Marsh Lake and Gantenbein Lake. Diamond Bluff Associates is responsible for regular maintenance and non-emergency repair of their dikes. The Corps of Engineers periodically enters into a written agreement with Diamond Bluff Associates allowing the Corps an easement to perform emergency repairs of the embankment system.

Xcel Energy Corporation owns and operates two hydroelectric projects that are tributary to Pool 3. The St. Croix Falls Dam located in St. Croix Falls, Wisconsin and the Apple River Falls Dam located 2 miles upstream of the Apple River confluence with the St. Croix River. Discharges from these two dams represent the total inflow of the St. Croix River to Pool No. 3 and are used for daily regulation by Water Control. Xcel Energy provides daily discharge values each morning to Water Control via a secure computer connection.

9-02. Interagency Coordination.

a. Local Press and Corps Bulletins. Information concerning regulation of Lock and Dam No. 3 is provided by the St. Paul District's Public Affairs Office (PAO) to the local news media in response to their requests. In addition, Construction and Operations Division coordinates with PAO to provide News Releases regarding the opening or closing of the lock to navigation.

b. National Weather Service. The National Weather Service (NWS) provides the St. Paul District a "Work 10" file daily by 0830-hours. The file contains the five-day forecast for tributaries to the Mississippi River lock and dam system. The five-day forecast includes the 24-hour quantitative precipitation forecast (QPF). These stage hydrographs are input to Mississippi Basin

Modeling System which is an unsteady flow model utilizing the computer program UNET. After the model is run, the output is sent to the NWS by 0930-hours. The NWS uses this information to forecast stages along the Mississippi River, which includes the tailwater of Lock and Dam No. 3 Red Wing).

c. **US Geological Survey.** To maintain the vast network of stream gages for operation of the locks and dams in the St. Paul District would be a costly undertaking. Because of the existing infrastructure of the US Geological Survey (USGS), the St. Paul District enters into a cooperative agreement each year with the USGS to maintain many of the gages on the Mississippi River and its tributaries. As for Pool No. 3, this includes the Mississippi River at Prescott, Wisconsin and the St. Croix River at St. Croix Falls Wisconsin. St. Paul District owns all the gage equipment. The USGS publishes the daily discharges for these two gages annually as part of their *Water Resources Data – Wisconsin*.

d. **River Resources Forum.** The River Resources Forum and the subcommittee, Water Level Management Task Force, shares information and provides recommendations to the Corps of Engineers on river management. Participants include the US Fish and Wildlife Service, US Geological Survey, US Environmental Protection Agency, National Park Service, US Coast Guard, US Department of Transportation, Departments of Natural Resources of Minnesota and Wisconsin, Departments of Transportation of Minnesota and Wisconsin, and representatives of the commercial navigation industry.

9-03. Reports. National Weather Service (NWS) Form B-91 contains pertinent weather information at the lock site. This is mailed to the NWS on the first of each month. The "Stevens Strip Charts" are sent to Water Control section at a minimum of once per year.

EXHIBIT A
SUPPLEMENTARY PERTINENT DATA

General Information

Location:	Mississippi River Mile 797.0 Red Wing, Minnesota Lat 44° 36' 36" N Long 92° 36' 36" W 18.3 miles below Lock and Dam No. 2 44.2 miles above Lock and Dam No. 4
Type of Project:	Lock and Dam for Navigation Purposes
Project Owner:	Corps of Engineers
Operating Agency:	St. Paul District; Construction-Operations Division
Regulating Agency:	St. Paul District; Water Control Section
Completion Date:	March 1938
Datum:	MSL – 1912 adjustment
Real Estate:	5,604.73 acres in fee 268.30 acres in flowage easement 67.90 acres to the Department of Interior 2,481.90 acres in fee above normal pool

Hydrology

Drainage Area:	45,170 square miles
Design Flood:	Flood of 1881 Design High Water: Elevation 682.2 ft Design Discharge: 134,000 cfs
Minimum Flow:	Of Record: 1934 Discharge 2,200 cfs Post Const, Nav-Season: Aug 1988 Discharge 1,600 cfs
Maximum Flow:	19 April 1965: Discharge 230,000 cfs
Average Annual Flow:	Years 1960-2002: Discharge 20,500 cfs
Maximum Monthly Flow:	April 1965: Discharge 115,340 cfs
Maximum Daily Flow:	23 April 1965: Discharge 224,800 cfs

Key Stream Flow Locations:	Mississippi River @ Prescott, Wisconsin St. Croix River @ Stillwater, Minnesota St. Croix River @ St. Croix Falls Dam, Wisconsin St. Croix River @ Grantsburg, Wisconsin
Data Recorded at Dam:	Pool and Tailwater Elevations (4-hr) Prescott, Wisconsin Elevation (4-hr) Stillwater, Minnesota Elevation (daily) Tainter Valve Opening (4-hr, winter only) Gate Openings (4-hr) Wind Speed & Direction (8-hr) Air Temperature (8-hr) Precipitation (daily) Water Temperature (daily) Maximum-Minimum Air Temperature (daily) Snow Depth and Water Content (weekly) Percent Pool and Tailwater Ice Coverage (weekly) Pool and Tailwater Ice Thickness (weekly)
Precipitation Gages:	Lock & Dam No. 2 and 3
Snow Survey:	At LD No. 3 (every Sunday by site personnel) St. Croix River Basin (late Feb by Gage Crew) Minnesota: Moose Lake, Hinkley, and Forest Lake Wisconsin: Hayward, Minong, Spooner, Danbury, Siren, Grantsburg, St. Croix Falls, and New Richmond

Physical Features

Lock:	Main Lock Chamber:	110 ft by 600 ft
	Top of Lock Walls:	Elevation 686.0 ft
	Top of Upper Gate Sill (main):	Elevation 658.0 ft
	Top of Upper Gate Sill (aux):	Elevation 656.0 ft
	Top of Lower Gate Sill:	Elevation 653.0 ft
	Lock Chamber Floor:	Elevation 652.5 ft
	Height of Upper Miter Gates (main):	25.0 feet
	Height of Upper Miter Gates (aux):	27.0 feet
	Height of Lower Miter Gates:	30.0 feet
	Lift:	8.0 feet
	Upper Guidewall Length:	519 feet
	Lower Guidewall Length:	504 feet
	Freeboard @ Project Pool:	11 feet
	Average Filling/Emptying Time:	10 minutes
	Average Single Lockage Time:	30 minutes
	Average Double Lockage Time:	1.5 to 2.0 hours

Moveable Dam:	Roller Gates: 4 Gates	80 feet by 20 feet
	Roller Gate Sill:	Elevation 655.0 ft
	Roller Gate End Sill:	Elevation 652.5 ft
	Roller Gate Submergence:	5 feet below Project Pool
	Bulkheads:	6 @ 4'- 2" by 85'- 4"
	Top of Bridge Deck:	Elevation 704.5 ft

Earthen Dams:	Length:	2,600 feet (Minnesota side)
		1,400 feet (Wisconsin side)
	Crest Elevation:	686.0 ft (Minnesota side)
		676.0 ft – 686.0 ft (Wisconsin side)
	Top Width:	20 feet
	Maximum Height:	14 feet
	Pool Side Slope:	1V:3H
	Tailwater Slope:	1V:5.5 H
	Slope Protection:	12 inch riprap
	To crest on pool side.	
	To elevation 669 ft on TW side.	

Spot Dikes:	Number:	10 Wisconsin Side (Dikes A – J)
		4 Minnesota Side (Vermillion, Treudale, Carter Slough Dikes, and Spot Dike K)
	Crest Elevation:	675.0 feet
	Top Width:	20 feet (Wisconsin side)
		10 feet (Minnesota side)
	Length:	50 – 500 feet (Wisconsin side)
		100 – 300 feet (Minnesota side)

Pool:	Normal (Project) Upper Pool:	Elevation 675.0 ft
	Normal (Project) Lower Pool:	Elevation 667.0 ft
	Total Pool Area (at Project Pool):	17,950 acres
		(Mississippi River Segment)
	Primary Control Point (Prescott):	Elevation 675.0 ft
	Secondary Control Point (dam):	Elevation 674.0 ft
	Length in River Miles:	18.3 miles
	Navigation Channel Width;	
	Straight Reaches:	300 feet
	Curved Reaches:	300-550 feet
	Most Frequent Dredge Site:	Coulters Island

STATION NUMBER 05344500 MISSISSIPPI RIVER AT PRESCOTT, WI SOURCE AGENCY USGS STATE 55 COUNTY 093
LATITUDE 444445 LONGITUDE 0924800 NAD27 DRAINAGE AREA 44800 CONTRIBUTING DRAINAGE AREA DATUM 649.5 NGVD29
Date Processed: 2003-09-23 By mitton Created by mitton: 03-11-2003 Updated by mitton: 03-13-2003

EXPANDED RATING TABLE

Gage height, feet	Discharge IN cfs .00	.01	.02	.03	.04	(STANDARD PRECISION) .05	.06	.07	.08	.09	DIFF IN Q PER .1 UNITS
28.00	32500*	32600	32600	32700	32700	32800	32800	32900	32900	33000	500
28.10	33000	33100	33100	33200	33200	33300	33300	33400	33400	33500	500
28.20	33500	33600	33600	33700	33700	33800	33800	33900	33900	34000	500
28.30	34000	34100	34100	34200	34200	34300	34300	34400	34400	34500	500
28.40	34500	34600	34600	34700	34700	34800	34800	34900	34900	35000	500
28.50	35000*	35100	35100	35200	35200	35300	35300	35400	35400	35500	500
28.60	35500	35600	35600	35700	35700	35800	35800	35900	35900	36000	500
28.70	36000	36100	36100	36200	36200	36300	36300	36400	36400	36500	500
28.80	36500	36600	36600	36700	36700	36800	36800	36900	36900	37000	500
28.90	37000	37100	37100	37200	37200	37300	37300	37400	37400	37500	600
29.00	37600*	37600	37700	37700	37800	37800	37900	37900	38000	38000	500
29.10	38100	38200	38200	38300	38300	38400	38400	38500	38500	38600	500
29.20	38600	38700	38800	38800	38900	38900	39000	39000	39100	39100	600
29.30	39200	39300	39300	39400	39400	39500	39500	39600	39600	39700	500
29.40	39700	39800	39900	39900	40000	40000	40100	40100	40200	40200	600
29.50	40300*	40400	40400	40500	40500	40600	40600	40700	40800	40800	600
29.60	40900	40900	41000	41100	41100	41200	41200	41300	41300	41400	600
29.70	41500	41500	41600	41600	41700	41700	41800	41900	41900	42000	500
29.80	42000	42100	42200	42200	42300	42300	42400	42400	42500	42600	600
29.90	42600	42700	42700	42800	42900	42900	43000	43000	43100	43100	600
30.00	43200*	43300	43300	43400	43500	43500	43600	43700	43700	43800	700
30.10	43900	44000	44000	44100	44200	44200	44300	44400	44400	44500	700
30.20	44600	44600	44700	44800	44800	44900	45000	45100	45100	45200	700
30.30	45300	45300	45400	45500	45500	45600	45700	45700	45800	45900	700
30.40	46000	46000	46100	46200	46200	46300	46400	46400	46500	46600	600
30.50	46600	46700	46800	46900	46900	47000	47100	47100	47200	47300	700
30.60	47300	47400	47500	47600	47600	47700	47800	47800	47900	48000	700
30.70	48000	48100	48200	48300	48300	48400	48500	48500	48600	48700	700
30.80	48700	48800	48900	49000	49000	49100	49200	49200	49300	49400	700
30.90	49400	49500	49600	49700	49700	49800	49900	49900	50000	50100	800
31.00	50200*	50200	50300	50400	50500	50600	50700	50700	50800	50900	800
31.10	51000	51100	51200	51200	51300	51400	51500	51600	51700	51800	800
31.20	51800	51900	52000	52100	52200	52300	52400	52400	52500	52600	900
31.30	52700	52800	52900	53000	53000	53100	53200	53300	53400	53500	900
31.40	53600	53600	53700	53800	53900	54000	54100	54200	54200	54300	800

Gage height, feet	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER .1 UNITS
	Discharge IN cfs					(STANDARD PRECISION)					
31.50	54400	54500	54600	54700	54800	54900	54900	55000	55100	55200	900
31.60	55300	55400	55500	55500	55600	55700	55800	55900	56000	56100	900
31.70	56200	56200	56300	56400	56500	56600	56700	56800	56900	56900	800
31.80	57000	57100	57200	57300	57400	57500	57600	57600	57700	57800	900
31.90	57900	58000	58100	58200	58300	58400	58400	58500	58600	58700	900
32.00	58800*	58900	59000	59100	59200	59300	59400	59500	59600	59700	1000
32.10	59800	59900	60000	60100	60200	60300	60400	60500	60600	60700	1000
32.20	60800	60900	61000	61100	61200	61300	61400	61500	61600	61700	1000
32.30	61800	61900	62000	62100	62200	62300	62400	62500	62600	62700	1000
32.40	62800	62900	63000	63100	63200	63300	63400	63500	63600	63700	1000
32.50	63800	63900	64000	64100	64200	64300	64400	64500	64600	64700	1000
32.60	64800	64900	65000	65100	65200	65300	65400	65500	65600	65700	1000
32.70	65800	65900	66000	66100	66200	66400	66500	66600	66700	66800	1100
32.80	66900	67000	67100	67200	67300	67400	67500	67600	67700	67800	1000
32.90	67900	68000	68100	68200	68300	68400	68500	68600	68700	68800	1100
33.00	69000*	69100	69200	69300	69400	69500	69600	69700	69800	69900	1100
33.10	70100	70200	70300	70400	70500	70600	70700	70800	70900	71000	1100
33.20	71200	71300	71400	71500	71600	71700	71800	71900	72100	72200	1100
33.30	72300	72400	72500	72600	72700	72800	73000	73100	73200	73300	1100
33.40	73400	73500	73600	73700	73900	74000	74100	74200	74300	74400	1100
33.50	74500	74600	74800	74900	75000	75100	75200	75300	75400	75600	1200
33.60	75700	75800	75900	76000	76100	76200	76400	76500	76600	76700	1100
33.70	76800	76900	77000	77200	77300	77400	77500	77600	77700	77900	1200
33.80	78000	78100	78200	78300	78400	78600	78700	78800	78900	79000	1100
33.90	79100	79200	79400	79500	79600	79700	79800	79900	80100	80200	1200
34.00	80300*	80400	80600	80700	80800	80900	81100	81200	81300	81400	1300
34.10	81600	81700	81800	82000	82100	82200	82300	82500	82600	82700	1200
34.20	82800	83000	83100	83200	83400	83500	83600	83700	83900	84000	1300
34.30	84100	84300	84400	84500	84600	84800	84900	85000	85200	85300	1300
34.40	85400	85600	85700	85800	85900	86100	86200	86300	86500	86600	1300
34.50	86700	86900	87000	87100	87300	87400	87500	87700	87800	87900	1300
34.60	88000	88200	88300	88400	88600	88700	88800	89000	89100	89200	1400
34.70	89400	89500	89600	89800	89900	90000	90200	90300	90400	90600	1300
34.80	90700	90800	91000	91100	91200	91400	91500	91600	91800	91900	1300
34.90	92000	92200	92300	92500	92600	92700	92900	93000	93100	93300	1400
35.00	93400*	93500	93700	93800	93900	94100	94200	94400	94500	94600	1400
35.10	94800	94900	95000	95200	95300	95400	95600	95700	95900	96000	1300
35.20	96100	96300	96400	96500	96700	96800	97000	97100	97200	97400	1400
35.30	97500	97600	97800	97900	98100	98200	98300	98500	98600	98800	1400
35.40	98900	99000	99200	99300	99400	99600	99700	99900	100000	100000	1100

Gage height, feet	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER .1 UNITS
	Discharge IN cfs					(STANDARD PRECISION)					
35.50	100000	100000	101000	101000	101000	101000	101000	101000	101000	102000	2000
35.60	102000	102000	102000	102000	102000	102000	103000	103000	103000	103000	1000
35.70	103000	103000	103000	104000	104000	104000	104000	104000	104000	104000	2000
35.80	105000	105000	105000	105000	105000	105000	105000	106000	106000	106000	1000
35.90	106000	106000	106000	106000	107000	107000	107000	107000	107000	107000	1000
36.00	107000*	108000	108000	108000	108000	108000	108000	108000	109000	109000	2000
36.10	109000	109000	109000	109000	109000	110000	110000	110000	110000	110000	1000
36.20	110000	110000	111000	111000	111000	111000	111000	111000	112000	112000	2000
36.30	112000	112000	112000	112000	112000	113000	113000	113000	113000	113000	1000
36.40	113000	113000	114000	114000	114000	114000	114000	114000	114000	115000	2000
36.50	115000	115000	115000	115000	115000	116000	116000	116000	116000	116000	1000
36.60	116000	116000	117000	117000	117000	117000	117000	117000	117000	118000	2000
36.70	118000	118000	118000	118000	118000	119000	119000	119000	119000	119000	1000
36.80	119000	119000	120000	120000	120000	120000	120000	120000	121000	121000	2000
36.90	121000	121000	121000	121000	121000	122000	122000	122000	122000	122000	1000
37.00	122000*	123000	123000	123000	123000	123000	123000	123000	124000	124000	2000
37.10	124000	124000	124000	124000	125000	125000	125000	125000	125000	125000	2000
37.20	126000	126000	126000	126000	126000	126000	126000	127000	127000	127000	1000
37.30	127000	127000	127000	128000	128000	128000	128000	128000	128000	129000	2000
37.40	129000	129000	129000	129000	129000	129000	130000	130000	130000	130000	1000
37.50	130000	130000	131000	131000	131000	131000	131000	131000	132000	132000	2000
37.60	132000	132000	132000	132000	133000	133000	133000	133000	133000	133000	2000
37.70	134000	134000	134000	134000	134000	134000	134000	135000	135000	135000	1000
37.80	135000	135000	135000	136000	136000	136000	136000	136000	136000	137000	2000
37.90	137000	137000	137000	137000	137000	138000	138000	138000	138000	138000	1000
38.00	138000*	139000	139000	139000	139000	139000	139000	140000	140000	140000	2000
38.10	140000	140000	140000	141000	141000	141000	141000	141000	141000	142000	2000
38.20	142000	142000	142000	142000	142000	143000	143000	143000	143000	143000	1000
38.30	143000	144000	144000	144000	144000	144000	144000	145000	145000	145000	2000
38.40	145000	145000	145000	146000	146000	146000	146000	146000	146000	147000	2000
38.50	147000	147000	147000	147000	147000	148000	148000	148000	148000	148000	1000
38.60	148000	149000	149000	149000	149000	149000	149000	150000	150000	150000	2000
38.70	150000	150000	150000	151000	151000	151000	151000	151000	152000	152000	2000
38.80	152000	152000	152000	152000	153000	153000	153000	153000	153000	153000	2000
38.90	154000	154000	154000	154000	154000	154000	155000	155000	155000	155000	1000
39.00	155000*	155000	156000	156000	156000	156000	156000	156000	157000	157000	2000
39.10	157000	157000	157000	157000	158000	158000	158000	158000	158000	158000	2000
39.20	159000	159000	159000	159000	159000	159000	160000	160000	160000	160000	1000
39.30	160000	160000	161000	161000	161000	161000	161000	161000	162000	162000	2000
39.40	162000	162000	162000	163000	163000	163000	163000	163000	163000	164000	2000

Gage height, feet	Discharge IN cfs .00	.01	.02	.03	.04	(STANDARD PRECISION) .05	.06	.07	.08	.09	DIFF IN Q PER .1 UNITS
39.50	164000	164000	164000	164000	164000	165000	165000	165000	165000	165000	1000
39.60	165000	166000	166000	166000	166000	166000	166000	167000	167000	167000	2000
39.70	167000	167000	167000	168000	168000	168000	168000	168000	168000	169000	2000
39.80	169000	169000	169000	169000	170000	170000	170000	170000	170000	170000	2000
39.90	171000	171000	171000	171000	171000	171000	172000	172000	172000	172000	1000
40.00	172000*	172000	173000	173000	173000	173000	173000	173000	174000	174000	2000
40.10	174000	174000	174000	174000	175000	175000	175000	175000	175000	175000	2000
40.20	176000	176000	176000	176000	176000	176000	177000	177000	177000	177000	1000
40.30	177000	177000	178000	178000	178000	178000	178000	179000	179000	179000	2000
40.40	179000	179000	179000	180000	180000	180000	180000	180000	180000	181000	2000
40.50	181000	181000	181000	181000	181000	182000	182000	182000	182000	182000	1000
40.60	182000	183000	183000	183000	183000	183000	183000	184000	184000	184000	2000
40.70	184000	184000	184000	185000	185000	185000	185000	185000	186000	186000	2000
40.80	186000	186000	186000	186000	187000	187000	187000	187000	187000	187000	2000
40.90	188000	188000	188000	188000	188000	188000	189000	189000	189000	189000	1000
41.00	189000*	189000	190000	190000	190000	190000	190000	191000	191000	191000	2000
41.10	191000	191000	191000	192000	192000	192000	192000	192000	192000	193000	2000
41.20	193000	193000	193000	193000	194000	194000	194000	194000	194000	194000	2000
41.30	195000	195000	195000	195000	195000	196000	196000	196000	196000	196000	1000
41.40	196000	197000	197000	197000	197000	197000	197000	198000	198000	198000	2000
41.50	198000	198000	199000	199000	199000	199000	199000	199000	200000	200000	2000
41.60	200000	200000	200000	201000	201000	201000	201000	201000	201000	202000	2000
41.70	202000	202000	202000	202000	203000	203000	203000	203000	203000	203000	2000
41.80	204000	204000	204000	204000	204000	205000	205000	205000	205000	205000	1000
41.90	205000	206000	206000	206000	206000	206000	207000	207000	207000	207000	2000
42.00	207000*	207000	208000	208000	208000	208000	208000	209000	209000	209000	2000
42.10	209000	209000	210000	210000	210000	210000	210000	210000	211000	211000	2000
42.20	211000	211000	211000	212000	212000	212000	212000	212000	213000	213000	2000
42.30	213000	213000	213000	213000	214000	214000	214000	214000	214000	215000	2000
42.40	215000	215000	215000	215000	216000	216000	216000	216000	216000	216000	2000
42.50	217000	217000	217000	217000	217000	218000	218000	218000	218000	218000	2000
42.60	219000	219000	219000	219000	219000	220000	220000	220000	220000	220000	1000
42.70	220000	221000	221000	221000	221000	221000	222000	222000	222000	222000	2000
42.80	222000	223000	223000	223000	223000	223000	224000	224000	224000	224000	2000
42.90	224000	224000	225000	225000	225000	225000	225000	226000	226000	226000	2000
43.00	226000*	226000	227000	227000	227000	227000	227000	228000	228000	228000	2000
43.10	228000	228000	228000	229000	229000	229000	229000	229000	230000	230000	2000
43.20	230000*										

"*" indicates a rating descriptor point

U.S. DEPARTMENT OF THE INTERIOR - U.S. GEOLOGICAL SURVEY - WATER RESOURCES

STATION NUMBER 05340500 ST. CROIX RIVER AT ST. CROIX FALLS, WI SOURCE AGENCY USGS STATE 55 COUNTY 095
LATITUDE 452425 LONGITUDE 0923849 NAD27 DRAINAGE AREA 6240 CONTRIBUTING DRAINAGE AREA DATUM 689.94 NGVD29
Date Processed: 2003-09-12 09:57 By pastark

EXPANDED RATING TABLE

Gage height, feet	Discharge IN cfs .00	.01	.02	.03	.04	(STANDARD PRECISION) .05	.06	.07	.08	.09	DIFF IN Q PER .1 UNITS
1.00	30.0*	33.0	36.0	39.0	42.0	45.0	48.0	51.0	54.0	57.0	30.0
1.10	60.0*	64.4	68.6	72.8	76.9	80.9	84.8	88.7	92.5	96.3	40.0
1.20	100*	105	110	115	120	125	130	135	140	145	50.0
1.30	150*	156	162	168	174	180	186	192	198	204	60.0
1.40	210*	216	223	229	236	242	249	255	262	268	65.0
1.50	275*	282	290	297	304	312	319	327	335	342	75.0
1.60	350*	358	366	374	383	391	399	407	416	424	83.0
1.70	433	441	450	458	467	476	485	493	502	511	87.0
1.80	520*	530	539	549	558	568	578	588	598	607	97.0
1.90	617	627	638	648	658	668	678	689	699	710	103
2.00	720*	732	744	756	768	780	792	805	817	829	122
2.10	842	854	867	880	893	905	918	931	945	958	129
2.20	971	984	998	1010	1020	1040	1050	1070	1080	1090	139
2.30	1110	1120	1140	1150	1160	1180	1190	1210	1220	1240	140
2.40	1250	1260	1280	1290	1310	1320	1340	1350	1370	1380	150
2.50	1400*	1420	1430	1450	1470	1490	1500	1520	1540	1560	180
2.60	1580	1590	1610	1630	1650	1670	1690	1710	1720	1740	180
2.70	1760	1780	1800	1820	1840	1860	1880	1900	1920	1940	200
2.80	1960	1980	2000	2020	2040	2060	2080	2100	2120	2140	200
2.90	2160	2180	2200	2220	2250	2270	2290	2310	2330	2350	220
3.00	2380	2400	2420	2440	2460	2490	2510	2530	2550	2580	220
3.10	2600	2620	2640	2670	2690	2710	2740	2760	2780	2810	230
3.20	2830	2850	2880	2900	2930	2950	2970	3000	3020	3050	240
3.30	3070	3100	3120	3150	3170	3200	3220	3250	3270	3300	250
3.40	3320	3350	3370	3400	3420	3450	3480	3500	3530	3550	260
3.50	3580*	3600	3630	3650	3680	3700	3730	3750	3770	3800	240
3.60	3820	3850	3870	3900	3920	3950	3970	4000	4020	4050	250
3.70	4070	4100	4120	4150	4170	4200	4230	4250	4280	4300	260
3.80	4330	4360	4380	4410	4430	4460	4490	4510	4540	4560	260
3.90	4590	4620	4640	4670	4700	4720	4750	4780	4810	4830	270
4.00	4860*	4890	4910	4940	4960	4990	5010	5040	5060	5090	260
4.10	5120	5140	5170	5190	5220	5250	5270	5300	5330	5350	260
4.20	5380	5400	5430	5460	5480	5510	5540	5560	5590	5620	260
4.30	5640	5670	5700	5720	5750	5780	5810	5830	5860	5890	270
4.40	5910	5940	5970	6000	6020	6050	6080	6110	6130	6160	280

Gage height, feet	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER .1 UNITS
			Discharge IN cfs			(STANDARD PRECISION)					
4.50	6190*	6210	6240	6260	6290	6310	6340	6360	6390	6410	250
4.60	6440	6460	6490	6510	6540	6560	6590	6610	6640	6660	250
4.70	6690	6710	6740	6760	6790	6810	6840	6860	6890	6910	250
4.80	6940	6960	6990	7010	7040	7070	7090	7120	7140	7170	250
4.90	7190	7220	7240	7270	7300	7320	7350	7370	7400	7420	260
5.00	7450*	7470	7500	7520	7550	7570	7590	7620	7640	7670	240
5.10	7690	7710	7740	7760	7790	7810	7830	7860	7880	7910	240
5.20	7930	7960	7980	8000	8030	8050	8080	8100	8130	8150	240
5.30	8170	8200	8220	8250	8270	8300	8320	8350	8370	8390	250
5.40	8420	8440	8470	8490	8520	8540	8570	8590	8620	8640	250
5.50	8670	8690	8720	8740	8760	8790	8810	8840	8860	8890	240
5.60	8910	8940	8960	8990	9010	9040	9060	9090	9110	9140	250
5.70	9160	9190	9210	9240	9260	9290	9310	9340	9360	9390	250
5.80	9410	9440	9460	9490	9510	9540	9570	9590	9620	9640	260
5.90	9670	9690	9720	9740	9770	9790	9820	9840	9870	9890	250
6.00	9920*	9940	9970	9990	10000	10000	10100	10100	10100	10100	280
6.10	10200	10200	10200	10200	10300	10300	10300	10300	10400	10400	200
6.20	10400	10400	10400	10500	10500	10500	10500	10600	10600	10600	200
6.30	10600	10700	10700	10700	10700	10800	10800	10800	10800	10900	300
6.40	10900	10900	10900	11000	11000	11000	11000	11100	11100	11100	200
6.50	11100	11200	11200	11200	11200	11300	11300	11300	11300	11300	300
6.60	11400	11400	11400	11400	11500	11500	11500	11500	11600	11600	200
6.70	11600	11600	11700	11700	11700	11700	11800	11800	11800	11800	300
6.80	11900	11900	11900	11900	12000	12000	12000	12000	12100	12100	200
6.90	12100	12100	12200	12200	12200	12200	12300	12300	12300	12300	300
7.00	12400*	12400	12400	12400	12500	12500	12500	12500	12600	12600	200
7.10	12600	12600	12700	12700	12700	12700	12800	12800	12800	12800	300
7.20	12900	12900	12900	12900	13000	13000	13000	13000	13100	13100	200
7.30	13100	13100	13200	13200	13200	13200	13300	13300	13300	13300	300
7.40	13400	13400	13400	13400	13500	13500	13500	13500	13600	13600	200
7.50	13600	13600	13700	13700	13700	13700	13800	13800	13800	13800	300
7.60	13900	13900	13900	13900	14000	14000	14000	14000	14100	14100	200
7.70	14100	14100	14200	14200	14200	14200	14300	14300	14300	14300	300
7.80	14400	14400	14400	14400	14500	14500	14500	14500	14600	14600	200
7.90	14600	14600	14700	14700	14700	14700	14800	14800	14800	14800	300
8.00	14900*	14900	14900	14900	15000	15000	15000	15000	15100	15100	200
8.10	15100	15100	15200	15200	15200	15200	15300	15300	15300	15300	300
8.20	15400	15400	15400	15400	15400	15500	15500	15500	15500	15600	200
8.30	15600	15600	15600	15700	15700	15700	15700	15800	15800	15800	200
8.40	15800	15900	15900	15900	15900	16000	16000	16000	16000	16100	300

Gage height, feet	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER .1 UNITS
			Discharge IN cfs			(STANDARD PRECISION)					
8.50	16100	16100	16100	16100	16200	16200	16200	16200	16300	16300	200
8.60	16300	16300	16400	16400	16400	16400	16500	16500	16500	16500	300
8.70	16600	16600	16600	16600	16700	16700	16700	16700	16800	16800	200
8.80	16800	16800	16900	16900	16900	16900	16900	17000	17000	17000	200
8.90	17000	17100	17100	17100	17100	17200	17200	17200	17200	17300	300
9.00	17300*	17300	17300	17400	17400	17400	17400	17500	17500	17500	200
9.10	17500	17600	17600	17600	17600	17700	17700	17700	17700	17800	300
9.20	17800	17800	17800	17900	17900	17900	17900	18000	18000	18000	200
9.30	18000	18000	18100	18100	18100	18100	18200	18200	18200	18200	300
9.40	18300	18300	18300	18300	18400	18400	18400	18400	18500	18500	200
9.50	18500	18500	18600	18600	18600	18600	18700	18700	18700	18700	300
9.60	18800	18800	18800	18800	18900	18900	18900	18900	19000	19000	200
9.70	19000	19000	19100	19100	19100	19100	19200	19200	19200	19200	300
9.80	19300	19300	19300	19300	19400	19400	19400	19400	19500	19500	200
9.90	19500	19500	19600	19600	19600	19600	19700	19700	19700	19700	300
10.00	19800*	19800	19800	19800	19800	19900	19900	19900	19900	20000	200
10.10	20000	20000	20000	20100	20100	20100	20100	20200	20200	20200	200
10.20	20200	20300	20300	20300	20300	20400	20400	20400	20400	20500	300
10.30	20500	20500	20500	20600	20600	20600	20600	20700	20700	20700	200
10.40	20700	20800	20800	20800	20800	20900	20900	20900	20900	21000	300
10.50	21000	21000	21000	21100	21100	21100	21200	21200	21200	21200	300
10.60	21300	21300	21300	21300	21400	21400	21400	21400	21500	21500	200
10.70	21500	21500	21600	21600	21600	21600	21700	21700	21700	21700	300
10.80	21800	21800	21800	21800	21900	21900	21900	21900	22000	22000	200
10.90	22000	22000	22100	22100	22100	22100	22200	22200	22200	22200	300
11.00	22300	22300	22300	22300	22400	22400	22400	22400	22500	22500	200
11.10	22500	22500	22600	22600	22600	22600	22700	22700	22700	22700	300
11.20	22800	22800	22800	22800	22900	22900	22900	22900	23000	23000	200
11.30	23000	23000	23100	23100	23100	23100	23200	23200	23200	23200	300
11.40	23300	23300	23300	23300	23400	23400	23400	23400	23500	23500	200
11.50	23500	23600	23600	23600	23600	23700	23700	23700	23700	23800	300
11.60	23800	23800	23800	23900	23900	23900	23900	24000	24000	24000	200
11.70	24000	24100	24100	24100	24100	24200	24200	24200	24200	24300	300
11.80	24300	24300	24300	24400	24400	24400	24400	24500	24500	24500	200
11.90	24500	24600	24600	24600	24600	24700	24700	24700	24700	24800	300
12.00	24800*	24800	24800	24900	24900	24900	24900	25000	25000	25000	200
12.10	25000	25100	25100	25100	25100	25200	25200	25200	25200	25300	300
12.20	25300	25300	25300	25400	25400	25400	25400	25500	25500	25500	200
12.30	25500	25600	25600	25600	25600	25700	25700	25700	25700	25800	300
12.40	25800	25800	25800	25900	25900	25900	25900	26000	26000	26000	200

Gage height, feet	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER .1 UNITS
			Discharge IN cfs			(STANDARD PRECISION)					
12.50	26000	26100	26100	26100	26100	26200	26200	26200	26200	26300	300
12.60	26300	26300	26300	26400	26400	26400	26400	26500	26500	26500	200
12.70	26500	26600	26600	26600	26600	26700	26700	26700	26700	26800	300
12.80	26800	26800	26800	26900	26900	26900	26900	27000	27000	27000	200
12.90	27000	27100	27100	27100	27100	27200	27200	27200	27200	27300	300
13.00	27300	27300	27300	27400	27400	27400	27400	27500	27500	27500	200
13.10	27500	27600	27600	27600	27600	27700	27700	27700	27700	27800	300
13.20	27800	27800	27800	27900	27900	27900	27900	28000	28000	28000	200
13.30	28000	28100	28100	28100	28100	28200	28200	28200	28200	28300	300
13.40	28300	28300	28300	28400	28400	28400	28400	28500	28500	28500	200
13.50	28500	28600	28600	28600	28600	28700	28700	28700	28700	28800	300
13.60	28800	28800	28800	28900	28900	28900	28900	29000	29000	29000	200
13.70	29000	29100	29100	29100	29100	29200	29200	29200	29200	29300	300
13.80	29300	29300	29300	29400	29400	29400	29400	29500	29500	29500	300
13.90	29600	29600	29600	29600	29700	29700	29700	29700	29800	29800	200
14.00	29800	29800	29900	29900	29900	29900	30000	30000	30000	30000	300
14.10	30100	30100	30100	30100	30200	30200	30200	30200	30300	30300	200
14.20	30300	30300	30400	30400	30400	30400	30500	30500	30500	30500	300
14.30	30600	30600	30600	30600	30700	30700	30700	30700	30800	30800	200
14.40	30800	30800	30900	30900	30900	30900	31000	31000	31000	31000	300
14.50	31100	31100	31100	31100	31200	31200	31200	31200	31300	31300	200
14.60	31300	31300	31400	31400	31400	31400	31500	31500	31500	31500	300
14.70	31600	31600	31600	31600	31700	31700	31700	31700	31800	31800	200
14.80	31800	31900	31900	31900	31900	32000	32000	32000	32000	32100	300
14.90	32100	32100	32100	32200	32200	32200	32200	32300	32300	32300	200
15.00	32300	32400	32400	32400	32400	32500	32500	32500	32500	32600	300
15.10	32600	32600	32600	32700	32700	32700	32700	32800	32800	32800	200
15.20	32800	32900	32900	32900	32900	33000	33000	33000	33000	33100	300
15.30	33100	33100	33100	33200	33200	33200	33200	33300	33300	33300	300
15.40	33400	33400	33400	33400	33500	33500	33500	33500	33600	33600	200
15.50	33600	33600	33700	33700	33700	33700	33800	33800	33800	33800	300
15.60	33900	33900	33900	33900	34000	34000	34000	34000	34100	34100	200
15.70	34100	34100	34200	34200	34200	34200	34300	34300	34300	34300	300
15.80	34400	34400	34400	34400	34500	34500	34500	34600	34600	34600	200
15.90	34600	34700	34700	34700	34700	34800	34800	34800	34800	34900	300
16.00	34900	34900	34900	35000	35000	35000	35000	35100	35100	35100	200
16.10	35100	35200	35200	35200	35200	35300	35300	35300	35300	35400	300
16.20	35400	35400	35400	35500	35500	35500	35500	35600	35600	35600	300
16.30	35700	35700	35700	35700	35800	35800	35800	35800	35900	35900	200
16.40	35900	35900	36000	36000	36000	36000	36100	36100	36100	36100	300

Gage height, feet	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER .1 UNITS
			Discharge IN cfs			(STANDARD PRECISION)					
16.50	36200	36200	36200	36200	36300	36300	36300	36300	36400	36400	200
16.60	36400	36400	36500	36500	36500	36500	36600	36600	36600	36700	300
16.70	36700	36700	36700	36800	36800	36800	36800	36900	36900	36900	200
16.80	36900	37000	37000	37000	37000	37100	37100	37100	37100	37200	300
16.90	37200	37200	37200	37300	37300	37300	37300	37400	37400	37400	200
17.00	37400	37500	37500	37500	37600	37600	37600	37600	37700	37700	300
17.10	37700	37700	37800	37800	37800	37800	37900	37900	37900	37900	300
17.20	38000	38000	38000	38000	38100	38100	38100	38100	38200	38200	200
17.30	38200	38200	38300	38300	38300	38400	38400	38400	38400	38500	300
17.40	38500	38500	38500	38600	38600	38600	38600	38700	38700	38700	200
17.50	38700	38800	38800	38800	38800	38900	38900	38900	38900	39000	300
17.60	39000	39000	39000	39100	39100	39100	39200	39200	39200	39200	300
17.70	39300	39300	39300	39300	39400	39400	39400	39400	39500	39500	200
17.80	39500	39500	39600	39600	39600	39600	39700	39700	39700	39700	300
17.90	39800	39800	39800	39900	39900	39900	39900	40000	40000	40000	200
18.00	40000	40100	40100	40100	40100	40200	40200	40200	40200	40300	300
18.10	40300	40300	40300	40400	40400	40400	40400	40500	40500	40500	200
18.20	40500	40600	40600	40600	40700	40700	40700	40700	40800	40800	300
18.30	40800	40800	40900	40900	40900	40900	41000	41000	41000	41000	300
18.40	41100	41100	41100	41100	41200	41200	41200	41300	41300	41300	200
18.50	41300	41400	41400	41400	41400	41500	41500	41500	41500	41600	300
18.60	41600	41600	41600	41700	41700	41700	41700	41800	41800	41800	200
18.70	41800	41900	41900	41900	42000	42000	42000	42000	42100	42100	300
18.80	42100	42100	42200	42200	42200	42200	42300	42300	42300	42300	300
18.90	42400	42400	42400	42400	42500	42500	42500	42600	42600	42600	200
19.00	42600	42700	42700	42700	42700	42800	42800	42800	42800	42900	300
19.10	42900	42900	42900	43000	43000	43000	43000	43100	43100	43100	300
19.20	43200	43200	43200	43200	43300	43300	43300	43300	43400	43400	200
19.30	43400	43400	43500	43500	43500	43500	43600	43600	43600	43600	300
19.40	43700	43700	43700	43800	43800	43800	43800	43900	43900	43900	200
19.50	43900	44000	44000	44000	44000	44100	44100	44100	44100	44200	300
19.60	44200	44200	44200	44300	44300	44300	44400	44400	44400	44400	300
19.70	44500	44500	44500	44500	44600	44600	44600	44600	44700	44700	200
19.80	44700	44700	44800	44800	44800	44800	44900	44900	44900	45000	300
19.90	45000	45000	45000	45100	45100	45100	45100	45200	45200	45200	200
20.00	45200	45300	45300	45300	45300	45400	45400	45400	45500	45500	300
20.10	45500	45500	45600	45600	45600	45600	45700	45700	45700	45700	300
20.20	45800	45800	45800	45800	45900	45900	45900	45900	46000	46000	200
20.30	46000	46100	46100	46100	46100	46200	46200	46200	46200	46300	300
20.40	46300	46300	46300	46400	46400	46400	46400	46500	46500	46500	300

Gage height, feet	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER .1 UNITS
			Discharge IN cfs			(STANDARD PRECISION)					
20.50	46600	46600	46600	46600	46700	46700	46700	46700	46800	46800	200
20.60	46800	46800	46900	46900	46900	46900	47000	47000	47000	47100	300
20.70	47100	47100	47100	47200	47200	47200	47200	47300	47300	47300	200
20.80	47300	47400	47400	47400	47400	47500	47500	47500	47600	47600	300
20.90	47600	47600	47700	47700	47700	47700	47800	47800	47800	47800	300
21.00	47900	47900	47900	47900	48000	48000	48000	48100	48100	48100	200
21.10	48100	48200	48200	48200	48200	48300	48300	48300	48300	48400	300
21.20	48400	48400	48400	48500	48500	48500	48600	48600	48600	48600	300
21.30	48700	48700	48700	48700	48800	48800	48800	48800	48900	48900	200
21.40	48900	48900	49000	49000	49000	49100	49100	49100	49100	49200	300
21.50	49200	49200	49200	49300	49300	49300	49300	49400	49400	49400	200
21.60	49400	49500	49500	49500	49600	49600	49600	49600	49700	49700	300
21.70	49700	49700	49800	49800	49800	49800	49900	49900	49900	50000	300
21.80	50000	50000	50000	50100	50100	50100	50100	50200	50200	50200	200
21.90	50200	50300	50300	50300	50300	50400	50400	50400	50500	50500	300
22.00	50500	50500	50600	50600	50600	50600	50700	50700	50700	50700	300
22.10	50800	50800	50800	50800	50900	50900	50900	51000	51000	51000	200
22.20	51000	51100	51100	51100	51100	51200	51200	51200	51200	51300	300
22.30	51300	51300	51400	51400	51400	51400	51500	51500	51500	51500	300
22.40	51600	51600	51600	51600	51700	51700	51700	51800	51800	51800	200
22.50	51800	51900	51900	51900	51900	52000	52000	52000	52000	52100	300
22.60	52100	52100	52100	52200	52200	52200	52300	52300	52300	52300	300
22.70	52400	52400	52400	52400	52500	52500	52500	52500	52600	52600	200
22.80	52600	52700	52700	52700	52700	52800	52800	52800	52800	52900	300
22.90	52900	52900	52900	53000	53000	53000	53100	53100	53100	53100	300
23.00	53200	53200	53200	53200	53300	53300	53300	53300	53400	53400	200
23.10	53400	53500	53500	53500	53500	53600	53600	53600	53600	53700	300
23.20	53700	53700	53700	53800	53800	53800	53800	53900	53900	53900	300
23.30	54000	54000	54000	54000	54100	54100	54100	54100	54200	54200	200
23.40	54200	54200	54300	54300	54300	54400	54400	54400	54400	54500	300
23.50	54500	54500	54500	54600	54600	54600	54600	54700	54700	54700	300
23.60	54800	54800	54800	54800	54900	54900	54900	54900	55000	55000	200
23.70	55000	55000	55100	55100	55100	55200	55200	55200	55200	55300	300
23.80	55300	55300	55300	55400	55400	55400	55400	55500	55500	55500	300
23.90	55600	55600	55600	55600	55700	55700	55700	55700	55800	55800	200
24.00	55800	55800	55900	55900	55900	56000	56000	56000	56000	56100	300
24.10	56100	56100	56100	56200	56200	56200	56200	56300	56300	56300	300
24.20	56400	56400	56400	56400	56500	56500	56500	56500	56600	56600	200
24.30	56600	56600	56700	56700	56700	56800	56800	56800	56800	56900	300
24.40	56900	56900	56900	57000	57000	57000	57100	57100	57100	57100	300

Gage height, feet	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER .1 UNITS
	Discharge IN cfs					(STANDARD PRECISION)					
24.50	57200	57200	57200	57200	57300	57300	57300	57300	57400	57400	200
24.60	57400	57500	57500	57500	57500	57600	57600	57600	57600	57700	300
24.70	57700	57700	57700	57800	57800	57800	57900	57900	57900	57900	300
24.80	58000	58000	58000	58000	58100	58100	58100	58100	58200	58200	200
24.90	58200	58300	58300	58300	58300	58400	58400	58400	58400	58500	300
25.00	58500	58500	58600	58600	58600	58600	58700	58700	58700	58700	300
25.10	58800	58800	58800	58800	58900	58900	58900	59000	59000	59000	200
25.20	59000	59100	59100	59100	59100	59200	59200	59200	59200	59300	300
25.30	59300	59300	59400	59400	59400	59400	59500	59500	59500	59500	300
25.40	59600	59600	59600	59700	59700	59700	59700	59800	59800	59800	200
25.50	59800	59900	59900	59900	59900	60000	60000	60000	60100	60100	300
25.60	60100	60100	60200	60200	60200	60200	60300	60300	60300	60300	300
25.70	60400	60400	60400	60500	60500	60500	60500	60600	60600	60600	200
25.80	60600	60700	60700	60700	60800	60800	60800	60800	60900	60900	300
25.90	60900	60900	61000	61000	61000	61000	61100	61100	61100	61200	300
26.00	61200	61200	61200	61300	61300	61300	61300	61400	61400	61400	300
26.10	61500	61500	61500	61500	61600	61600	61600	61600	61700	61700	200
26.20	61700	61700	61800	61800	61800	61900	61900	61900	61900	62000	300
26.30	62000	62000	62000	62100	62100	62100	62200	62200	62200	62200	300
26.40	62300	62300	62300	62300	62400	62400	62400	62400	62500	62500	200
26.50	62500	62600	62600	62600	62600	62700	62700	62700	62700	62800	300
26.60	62800	62800	62900	62900	62900	62900	63000	63000	63000	63000	300
26.70	63100	63100	63100	63200	63200	63200	63200	63300	63300	63300	200
26.80	63300	63400	63400	63400	63400	63500	63500	63500	63600	63600	300
26.90	63600	63600	63700	63700	63700	63700	63800	63800	63800	63900	300
27.00	63900	63900	63900	64000	64000	64000	64000	64100	64100	64100	300
27.10	64200	64200	64200	64200	64300	64300	64300	64300	64400	64400	200
27.20	64400	64400	64500	64500	64500	64600	64600	64600	64600	64700	300
27.30	64700	64700	64700	64800	64800	64800	64900	64900	64900	64900	300
27.40	65000	65000	65000	65000	65100	65100	65100	65200	65200	65200	200
27.50	65200	65300	65300	65300	65300	65400	65400	65400	65400	65500	300
27.60	65500	65500	65600	65600	65600	65600	65700	65700	65700	65700	300
27.70	65800	65800	65800	65900	65900	65900	65900	66000	66000	66000	200
27.80	66000	66100	66100	66100	66200	66200	66200	66200	66300	66300	300
27.90	66300	66300	66400	66400	66400	66500	66500	66500	66500	66600	300
28.00	66600	66600	66600	66700	66700	66700	66800	66800	66800	66800	300
28.10	66900	66900	66900	66900	67000	67000	67000	67000	67100	67100	200
28.20	67100	67200	67200	67200	67200	67300	67300	67300	67300	67400	300
28.30	67400	67400	67500	67500	67500	67500	67600	67600	67600	67600	300
28.40	67700	67700	67700	67800	67800	67800	67800	67900	67900	67900	200

Gage height, feet	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER .1 UNITS
			Discharge IN cfs			(STANDARD PRECISION)					
28.50	67900	68000	68000	68000	68100	68100	68100	68100	68200	68200	300
28.60	68200	68200	68300	68300	68300	68400	68400	68400	68400	68500	300
28.70	68500	68500	68500	68600	68600	68600	68700	68700	68700	68700	300
28.80	68800	68800	68800	68800	68900	68900	68900	69000	69000	69000	200
28.90	69000	69100	69100	69100	69100	69200	69200	69200	69300	69300	300
29.00	69300	69300	69400	69400	69400	69400	69500	69500	69500	69600	300
29.10	69600	69600	69600	69700	69700	69700	69700	69800	69800	69800	300
29.20	69900	69900	69900	69900	70000	70000	70000	70000	70100	70100	200
29.30	70100	70100	70200	70200	70200	70300	70300	70300	70300	70400	300
29.40	70400	70400	70400	70500	70500	70500	70600	70600	70600	70600	300
29.50	70700	70700	70700	70700	70800	70800	70800	70900	70900	70900	200
29.60	70900	71000	71000	71000	71000	71100	71100	71100	71200	71200	300
29.70	71200	71200	71300	71300	71300	71400	71400	71400	71400	71500	300
29.80	71500	71500	71500	71600	71600	71600	71700	71700	71700	71700	300
29.90	71800	71800	71800	71800	71900	71900	71900	72000	72000	72000	200
30.00	72000	72100	72100	72100	72100	72200	72200	72200	72300	72300	300
30.10	72300	72300	72400	72400	72400	72400	72500	72500	72500	72600	300
30.20	72600	72600	72600	72700	72700	72700	72700	72800	72800	72800	300
30.30	72900	72900	72900	72900	73000	73000	73000	73000	73100	73100	200
30.40	73100	73200	73200	73200	73200	73300	73300	73300	73300	73400	300
30.50	73400*										

"*" indicates a rating descriptor point

CENCS-ED-GH (1110-2-1403)

August 9, 1993
SVDobberpuhl//0638

MEMORANDUM FOR RECORD

SUBJECT: Locks and Dam No. 3 Emergency Actions Related to 1 August 1993 Towboat Accident

1. On 1 August 1993 a towboat accident described in the newspaper article (Enclosure 1) required emergency actions on the part of the Hydraulics and Geotechnical Sections as discussed in the following paragraphs.

2. <u>1930-2230 Sunday August 1, 1993 - 3 hours.</u> In response to a call from Mr. Robert Post at 1830, Mr. Stuart Dobberpuhl went to the District Office, located drawings for the Locks and Dam No. 3 project, and met with Mr. Kelcy Willis of Water Control.

3. The Regulation Manual for Locks and Dam No. 3 did not include sufficient information for a good understanding of the Spot Dikes upstream of Locks and Dam No. 3 or the limitations of the erosion protection located downstream of the stilling basins for the Roller Gates. For more information, the references of value were:

a. **Brownline Survey Drawings.** These drawings (Drawings M-S-13/4 through 10, inclusive) show the plan view locations of the spot dikes for Locks and Dam No. 3.

b. ***REPORT, Mississippi River, Pool 3 Dike Evaluation, January, 1987, U.S. Army Corps of Engineers, St. Paul District*** prepared by McCombs-Knutson Assoc., Inc. This report has not been finalized and sent forward to NCD. However, the report contains good background information with regard to the Pool 3 dikes and, also, provides project recommendations.

c. ***Technical Report HL-87-4, SCOUR PROTECTION FOR LOCKS AND DAMS 2-10, UPPER MISSISSIPPI RIVER, Hydraulic Model Investigation*** by Jerry V. Markussen, Steven C. Wilhelms, Hydraulics Laboratory, DEPARTMENT OF THE ARMY, Waterways Experiment Station, Corps of Engineeers, PO Box 631, Vicksburg, Mississippi 39180-0631. Included in this report is the documentation of the physical model testing and design recommendations for the scour protection for Locks and Dams 2-10.

4. Mr. Kelcy Willis was concerned about the rate of rise of the pool with the loss of capacity created by the sinking barge. The pool had risen 0.8 foot initially. The water control manual lacked information regarding the additional flow capacity beyond what is provided by the 4 roller gates.

5. Mr. Ed Eaton also came into the office in response to the emergency and took part in the telephone conferences and decisions relating to Water Control. Telephone conversations with Mr. Robert Post took place with regard to the situation alongwith a meeting in Mr. Jim Nicholson's office. That meeting was attended by Mr. Jim Nicholson, Mr. Dennis Cin, Mr. Mark Edlund, Mr. Dave Christenson, Mr. Ed Eaton and Mr. Stuart Dobberpuhl. The subject of increases in the pool elevation due to the loss of capacity was discussed. It was felt that the capacity provided by overtopping of the Wisconsin and Minnesota spot dikes systems would help alleviate substantial stage increases. One of the concerns discussed at the meeting was the operation of the 4 roller gates. In

an attempt to avoid potential problems with local scour in the area of the sunken barge, a decision was made to close Roller Gates 1 and 2. With the gates closed, about one foot of water would flow over the Roller Gates 1 and 2 at that time.

6. 0830-1230 Monday August 2, 1993 - 4 hours. During this time period, Mr. Stuart Dobberpuhl briefed Mr. Pat Foley of the situation concerning Locks and Dam No. 3, reviewed the WES model study report for the Scour Protection for the Locks and Dams, and made preparations for the helicopter reconnaissance of the spot dike system for Pool 3. Rough calculations at this time indicated that the endsill velocities for Roller Gates 3 and 4 were on the order of 11 feet per second. These velocities were considered high for long durations. Therefore, Mr. Kelcy Willis in Water Control was contacted and a recommendation was made to operate the gates so that the endsill velocities could be reduced to the 6 fps maximum value in accordance with the table in the regulation manual for when the gates are in the water. The regulation manual does not address a situation as existed at this time when all four gates are not full open for open river conditions. Normally, when open river conditions exist, the head differential across the dam is less than one foot and all four gates full open result in end sill velocities that are relatively low.

7. 1300-1530 Monday August 2, 1993 - 2.5 hours. The Wisconsin Spot Dikes, the two systems of private dikes on Gaintenbein's land, and the Spot dikes on the Vermillion River were inspected by helicopter. Mr. Dave Christenson arranged for Mr. Mark Dunaski, pilot for the State Highway Patrol, to fly the area. Since the helicopter provided by the State Highway Patrol for the inspection had room for only one passenger, the pilot landed at the Red Wing airport to allow Paul Madison a chance to also view the spot dike system from the helicopter. Photographs were taken with a 35mm camera. The aerial inspection was necessary due to the inaccessibility of the Gaintenbein area and the need to quickly identify potential areas where the spot dikes could breach. The results of the inspection indicated that:

a. One critical area upstream is at the sag located between Spot Dike A and Spot Dike B.

b. One critical area downstream is the private dike downstream and upstream of where rock protection was placed by Construction Operations Division earlier this year. This is a relatively long overflow reach where water from the lower pool, created by the Gaintenbein dike system, enters the main channel of the Mississippi River. Water was overflowing a relatively narrow strip of land with a width as narrow as 50 feet. What made this critical is the 2-3 foot head differential that existed across the narrow strip of land which was not protected against erosion. The only protection against erosion was the vegetation including tree roots which could not be expected to last over a long duration.

c. Another critical area downstream is in the area immediately downstream of Spot Dike A along the left bank of the main channel of the Mississippi River to the location of the 300 foot restricted area sign placed by the Minnesota DNR. The Corps also had installed a restricted area sign 150 downstream of the centerline of the bridge on the dam. The Corps sign is still intact. However, the DNR sign had collapsed as a result of the erosion that had taken place in this reach.

d. The combination of the critical areas immediately upstream and downstream of Spot Dike A as described above in subparagraphs a and c indicated the potential for a situation where a new channel could be formed that would bypass the dam and cause loss of the pool especially if the high head differential continued to exist over a long duration. At this time, the time required for removal of the sunken barge was uncertain. The headloss across the dike system at this point also appeared on the order of 2-3 feet which is a relatively large headloss for the type of dike that was being overtopped.

e. The Corps Spot Dikes A through J other than the area between Spot Dikes A and B appeared to be in relatively good condition from the aerial inspection. Significant portions of the Spot Dikes other than the sag areas appeared to be either above the water or appeared to have very shallow depths of flow over the crest.

f. The headloss across the Corps Spot Dikes A through J was estimated as roughly 0.5 foot or less.

g. The headloss across the intermediate Gaintenbein dike system was estimated as roughly 0.5 foot or less.

h. The headloss across the downstream Gaintenbein dike system and the private dike described above in subparagraph c was estimated as roughly 2-3 feet.

8. <u>1530-1700 Monday August 2, 1993 - 1.5 hours.</u> During this time, hydraulic data was reviewed and a meeting was held in the conference room. The meeting was attended by Mr. Robert Post, Mr. Jim Nicholson, Mr. Helmer Johnson, Mr. Dave Rydeen, Mr. Mike Lesher, and Mr. Stuart Dobberpuhl. Mr. Paul Madison and Mr. Stuart Dobberpuhl presented a summary of the results of the aerial reconnaissance and the hydraulic/geotechnical aspects. Paragraphs 3 and 4 discuss the concerns discussed at this meeting. At the conclusion of this meeting, a decision was made to limit flow through Roller Gates 3 and 4 so that the endsill velocities would not exceed 8 fps temporarily until soundings could be obtained to monitor the scour downstream of Roller Gates 3 and 4.

9. <u>0830-1230 Tuesday August 3, 1993 - 4 hours.</u> Hydraulic computations were developed to determine what velocities corresponded to the design conditions for half-gate and full-gate opening per the WES model study.

10. <u>1300-1400 Tuesday August 3, 1993 - 1 hour.</u> At this time another meeting held in ED-GH for the purpose of briefing Mr. Helmer Johnson of the Hydraulic, Geotechnical, and Water Control concerns. One of the concerns at this time was the problem of the pool rising to higher levels than what was desired. Other concerns relating to the velocities with the large gate openings were also discussed. At this time, initial information received verbally indicated that the soundings were showing that there had been no displacement of the capstone immediately downstream of the stilling basin.

11. <u>1400-1900 Tuesday August 3, 1993 - 5 hours.</u> Mr. Paul Madison and Mr. Stuart Dobberpuhl inspected the project site and met with Mr. Joe Lechner regarding the soundings. The soundings taken on Tuesday morning were reviewed and compared to the October 1992 soundings which Mr. Joe Lechner had at the site. The review indicated that the capstone indeed was still in place downstream of Roller Gates 3 and 4. However, the soundings also indicated that 30 feet of additional scour had occurred at a distance of about 200 feet downstream of Roller Gates 3 and 4 between October 1992 and August 3, 1993. Paul Madison and Stuart Dobberpuhl drove back to the District Office. Stuart Dobberpuhl then plotted up the sections obtained from the sounding crew. Enclosure 2 illustrates the section downstream of the centerline of Roller Gate 4. Enclosures 3 and 4 were developed using and updating the Locks and Dams No. 3 Fastabs 2-D model data for the outdraft study. The enclosures, which were developed by Mr. Scott Jutila, illustrate the migration of the deeper scour toward the area downstream of Roller Gates 3 and 4.

12. <u>0800-1000 Wednesday August 4, 1993 - 2 hours.</u> A meeting was held in the small conference room adjacent to Rooms 1219-1220 for the purpose of briefing Mr. Robert Post and Mr. Jim Nicholson. The meeting was attended by Mr. Robert Post, Mr. Jim Nicholson, Mr. Helmer Johnson, Mr. Paul Madison, and Mr. Stuart Dobberpuhl. At this meeting, the conclusion was that additional monitoring of the scour was needed. The plan was for Paul Madison and Stuart Dobberpuhl to make a field inspection. Mr. Craig Hinton and Mr. Dave Rydeen were assigned the

task of developing a contingency plan in the event that emergency actions were required.

13. <u>1000-1130 Wednesday August 4, 1993 - 1.5 hours.</u> Mr. Paul Madison and Mr. Stuart Dobberpuhl made a field reconnaissance of the area downstream of Locks and Dam No. 3 on the left bank by boat, the Gaintenbein private dike system along the left bank of the Mississippi River, and the Wisconsin Spot Dike System of Dikes A through J. Those participating in the boat inspection included Arden Duvall, Paul Madison and Stuart Dobberpuhl. The inspection indicated that the abnormal head across the dam and Spot Dike system had created a scour problem that needed remedial action. Flow from the area between Spot Dikes A and B upstream could pass into the intermediate pool created by the private dike system from Spot Dike A to the bluff on the Wisconsin side. Then, immediately downstream of Spot Dike A, the dike was being overtopped with about 2.5 - 3.0 feet of headloss. The waterfall and the water rushing towards the scour hole downstream of Roller Gates 3 and 4 created a precarious situation. Downstream of the waterfall, a channel was forming and outleting in the area between spot Dike A and the 150 foot and 300 foot Restricted Area signs. Making matters worse was the proximity of the flow outleting from this area towards the newly formed deep scour in the main channel of the Mississippi River downstream of Roller Gates 3 and 4. During the inspection, clusters of trees were being undermined by erosion. The clusters of trees could be heard and seen crashing into the water. As time passed, more and more of the eroded trees were carried downstream by the current. Based on these observations, Mr. Madison and Mr. Stuart Dobberpuhl concluded that emergency action consisting of placing a rock dike was justified. Very little progress had been made in removing the sunken barge. It was also uncertain how long the high head differential would be present across the Spot Dike System. The rock dike proposed tied into high ground at about the location of the 300 foot restricted area sign placed by the Minnesota DNR. The new rock dike redirected flow from the Gaintenbein area to a location downstream of the dam and the scour hole in the main channel of the Mississippi River. In the process of accomplishing that, the tailwater on the private dike was raised and high velocities adjacent to the downstream side of Spot Dike A were reduced.

14. <u>1130 - 2130 Wednesday August 4, 1993 - 10 hours.</u> During this time, Mr. Madison and Mr. Stuart Dobberpuhl, were involved with details for the construction of a 400 foot rock dike. This consisted of a preliminary determination of alignment, height and length. Since this was an emergency situation, no detailed drawings were developed and construction details were discussed verbally with Construction-Operations personnel in charge of the construction. Permission was also obtained from the caretaker for the Gaintenbein property for the construction of the emergency rock dike. The plan at this time was for Mr. Madison and Mr. Stuart Dobberpuhl to stay only long enough to provide the information needed for construction and review the soundings from Launch 16 which was to provide more detailed sonar soundings. However, when the sonar soundings were available, the soundings (Enclosure 5) obtained indicated excessive depths of scour. After discussions with Mr. Joe Lechner, it was decided that since the sonar soundings were obtained with Roller Gates 3 and 4 open, new soundings were needed with Roller Gates 3 and 4 closed. Mr. Lechner felt that the turbulence was too excessive for good readings with the gates open. Permission was not given earlier for closing the gates because of the concern about the high pool elevations that existed.

15. <u>2130-2400 Wednesday August 4, 1993 - 2.5 hours.</u> During this time, Mr. Paul Madison and Mr. Stuart Dobberpuhl waited for a second set of sonar soundings to be obtained, discussed options with regard to plan of action in the event that the sonar soundings were correct. At about midnight, the new soundings were obtained. The new soundings (Enclosure 6) indicated realistic elevations downstream of Roller Gate 3, at the endsill and other locations but indicated that severe scour of the area with capstone had developed downstream of Roller Gate 4. This created concern while at the same time doubt existed about the

reliability of the sonar soundings obtained under turbulent conditions. Therefore, a continued effort was made to obtain reliable sounding information. At this time, evidence for the sonar soundings being correct included:

a. Joe Lechner previously had not had problems in obtaining good data from the equipment on Launch 16.

b. The scour pattern looked realistic. The contours downstream of Roller Gate 4 appeared to follow the flow lines.

c. The deepest scour hole downstream of Roller Gates 1 and 2 had shifted to the area downstream of Roller Gates 3 and 4 based on the lead weight soundings obtained earlier in the day and on August 3, 1993 as compared to October 1992. This is illustrated on Enclosures 3 and 4.

d. Roller Gates 3 and 4 had been operated with higher velocities than what the riprap was designed for. Prior to when the gates were changed from an open river condition to being partially closed, the open river velocities were on the order of 12 fps versus 6 fps for the design condition with long duration, half gate open position, and normal pool (El. 675) and tailwater (El. 667) conditions.

e. Even though velocities were kept at roughly 8 fps, the impact of the higher velocities and the rate of erosion is very difficult to predict alongwith the actual timing of failure. Therefore, it could have been possible that damage could have been done to the capstone and rockfill material during open river conditions without being reflected in the soundings on Wednesday morning. Then, with velocities of 8 fps which still exceed the design condition velocities, erosion of the downstream end of the capstone could have started an unraveling process which took place in a relatively short period of time. Note that for Roller Gate 4, the original design section for the scour repair did not extend very far downstream since the deeper scour hole at that time (April 1983 Drawings) was just below Roller Gates 1 and 2. In addition, the rockfill section at this location was relatively thin. Section GB-4 on drawing M-P3-61/3 indicates a vertical depth of rock fill on the order of 3-4 feet. The bottom of the riprap is at elevation 630 which was then at the bottom of scour. Now, even the lead weight soundings had indicated that the bottom of the scour hole was at elevation 605. Therefore, a 25 foot depth of material had been eroded just downstream of the toe of the erosion protection.
The potential existed for an unraveling of the rock protection since it was placed on top of erodible material without adequate toe protection.

At the time, the evidence indicating that the sonar could be wrong included:

a. The first set of sonar soundings included data which was erroneous.

b. When the method of sounding was changed, the results changed dramatically indicating that the change might be due to the method of sounding.

c. The scour hole appeared to have stabilized when a comparison of the August 3 and 4 data was made.

16. <u>0000-0350 Thursday August 5, 1993 - 4 hours.</u> If the sonar soundings were correct, the capstone would have eroded and been transported downstream. Erosion would have been taking place in highly erodible sand and the integrity of the structure would have been threatened. Considering the consequences if the sonar soundings were correct, the soundings needed to be verified by the same method as was used for the earlier soundings. At 0100 it was known that another two barge loads of rock were expected to arrive at about 0800. After consultation with Mr. Ed Eaton who talked to Mr. Robert Post, Roller Gates 3 and 4 were closed. Mr. Dennis Erickson also needed a decision with regard to whether to place the rock on the left bank between spot dike A or wait and place the rock

downstream of the endsill for Roller Gate 4. A decision was made to initiate construction of the rock dike as planned. Roller Gates 3 and 4 remained closed until 0350 when the lead weight soundings indicated that the capstone downstream of Roller Gate 4 was still in place and that the sonar soundings were providing erroneous readings.

17. 0350-1115 Thursday August 5, 1993 - 7 hours. During this time, the construction of the rock dike was observed and Mr. Jim Nicholson and Mr. Robert Post were briefed concerning the status of the soundings and the construction of the rock dikes. The data available was organized for the next person from the Geotechnical Section who would be at the site to replace Paul Madison and Stuart Dobberpuhl. Paul Madison and Stuart Dobberpuhl arrived back at the District Office parking area and proceeded home.

18. 0830-1720 Friday August 6, 1993 - 8 hours. In the office, Water Control had questions regarding the best procedures for operation of the gates for different scenarios. These issues were discussed with Kelcy Willis of Water Control. During the discussions, Dennis Erickson of Construction Operations was consulted. One question asked was with regard to whether or not it would be acceptable to operate the gates with essentially higher velocities for a short duration. The intent was to lower the pool as much as possible and then create a surge which in the past on other recovery projects had helped break barges loose. In this case, the sharp edge of the pier between Roller Gates 1 and 2 cut into the edge of the barge making it difficult for the salvage operation. In the early afternoon, word was received that the sunken barge was removed. At about 1600, Mr. Stuart Dobberpuhl received a call from Mr. Joe Lechner that the soundings were completed and that the sounding data obtained on 6 August 1993 would be faxed. Mr. Stuart Dobberpuhl plotted the section downstream of the centerline of Roller Gate 4 and reviewed the numbers for the other sections. That information indicated that the scour hole downstream of Roller Gate 4 had not gotten worse.

19. Future Actions. In the future, the following is suggested for consideration:

a. Inspections of all Spot Dikes both on the Minnesota and Wisconsin sides of the Mississippi River and also the private dike systems in the Gaintenbein area for the purpose of determining the extent of erosion that may have occurred.

b. Evaluation of the scour protection downstream of the stilling basins, especially, the area downstream of Roller Gates 3 and 4 and the adjacent left bank. In the areas downstream of Roller Gates 1 and 2 the scour protection was carried to the bottom of the scour hole at elevation 605 during the repair in 1983. In 1983, the scour protection was only carried down to elevation 630 downstream of Roller Gate 4 since that was the bottom of the scour hole at that time. Using the same logic for the scour protection that was used at that time, the scour protection downstream of Roller Gates 3 and 4 should now be extended down the slope to the bottom of the scour hole at roughly elevation 605.

20. The information from this incident can be utilized for future studies. The accounts of this accident indicate that:

1. Wind was a major factor in the cause of this accident.

2. The potential for more serious consequences of this accident existed. One example is the position of the gates. If the discharge had been 36,000 cfs or lower instead of 42,000 cfs, the gates would have been lowered to the water under secondary control instead of open river conditions. If the gates had been lowered, the potential for damage to the gates would have been greater considering that two barges passed through the gate openings in this accident. Another scenario is the potential situation that could have occurred had the barges not passed through the gate openings. In that event, it would have been

possible that two more barges could have sunk making the recovery operation more difficult or possibly even affecting the flow capacity of Roller Gates 3 and 4, thereby, forcing most of the flow to pass over the Spot Dikes.

3. The greatest headloss during this event was at the downstream private dike system on the land owned by Gaintenbein. This is documented with the Pool, Tailwater readings for Locks and Dam No. 3 along with visual observations and data from the gage installed just downstream of Spot Dike A for this event. This also illustrates the potential for additional headloss for the Corps Spot Dike system should substantial failure of the private dikes occur.

STUART V. DOBBERPUHL
Hydraulic Engineer
Hydraulics Section
Geotechnical, Hydraulics
and Hydrologic Engineering Branch

ENCL 1

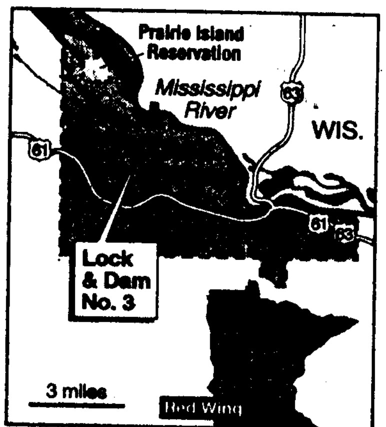
Winds, current sink one barge, damage two

By Richard Meryhew
Staff Writer

A barge filled with soybeans sank and two others were damaged Sunday when high winds and a powerful current sent them crashing into a Mississippi River dam near Red Wing, Minn.

The barges were part of a 12-barge load that was pulled sideways by the wind and waters as a southbound towboat tried to guide it into U.S. Lock and Dam No. 3, six miles north of Red Wing.

Ken Gardner, a spokesman for the U.S. Army Corps of Engineers, said it was the first barge sinking at the site in 30 years.



Star Tribune Map

Nobody was injured in the incident, although several barge crewmen were rescued with help from another towboat, Gardner said.

The lock and dam remained closed to river traffic yesterday while officials from the U.S. Coast Guard investigated the incident. Efforts also began to recover the sunken barge, which is blocking one of the dam's four gates.

Mike Lindgren, vice president of operations for Riverway Co. of Minneapolis, which owns the barges involved in the incident, said yesterday that it could take several days to recover the sunken barge. A crane barge will be at the site today to help lift the barge from the river bottom.

The accident occurred about 2 p.m. Sunday as the towboat "Hornet" steered the barges through a curve in the river channel and toward the lock.

The bend, just north of the lock and dam, makes that stretch of the Mississippi difficult to navigate. Often, additional boats are used to help guide the load into the lock, Gardner said.

But high winds and a current made stronger by flooding apparently made the task more treacherous than usual Sunday. At one point, Gardner said, the current pulled the load sideways into the river.

"There's always bad currents in here," he said. "It's an odd physical layout. There's always current trying to go into the dam."

Three barges broke away from the tow and hit a corner of the dam. Two eventually were pushed through the dam gates, which were partially open because of the high water. They were later recovered and tied together downstream. The third barge sank and its soybeans were lost.

The accident occurred one month after Lock and Dam No. 3 reopened to river traffic after flooding near Red Wing. The river channel remained closed south of Davenport, Iowa, because flood waters in Iowa, Illinois and Missouri have not receded to levels that would allow for safe river traffic.

Towing industry officials have recently said they are losing $1 million a day because of the shutdown.

Chanhassen Dinner Theatres sold to Los Angeles firm

By Mike Steele
Staff Writer

Chanhassen Dinner Theatres, at 25 one of the oldest and most successful ...

London and New York, which sold them to Century Park last week.

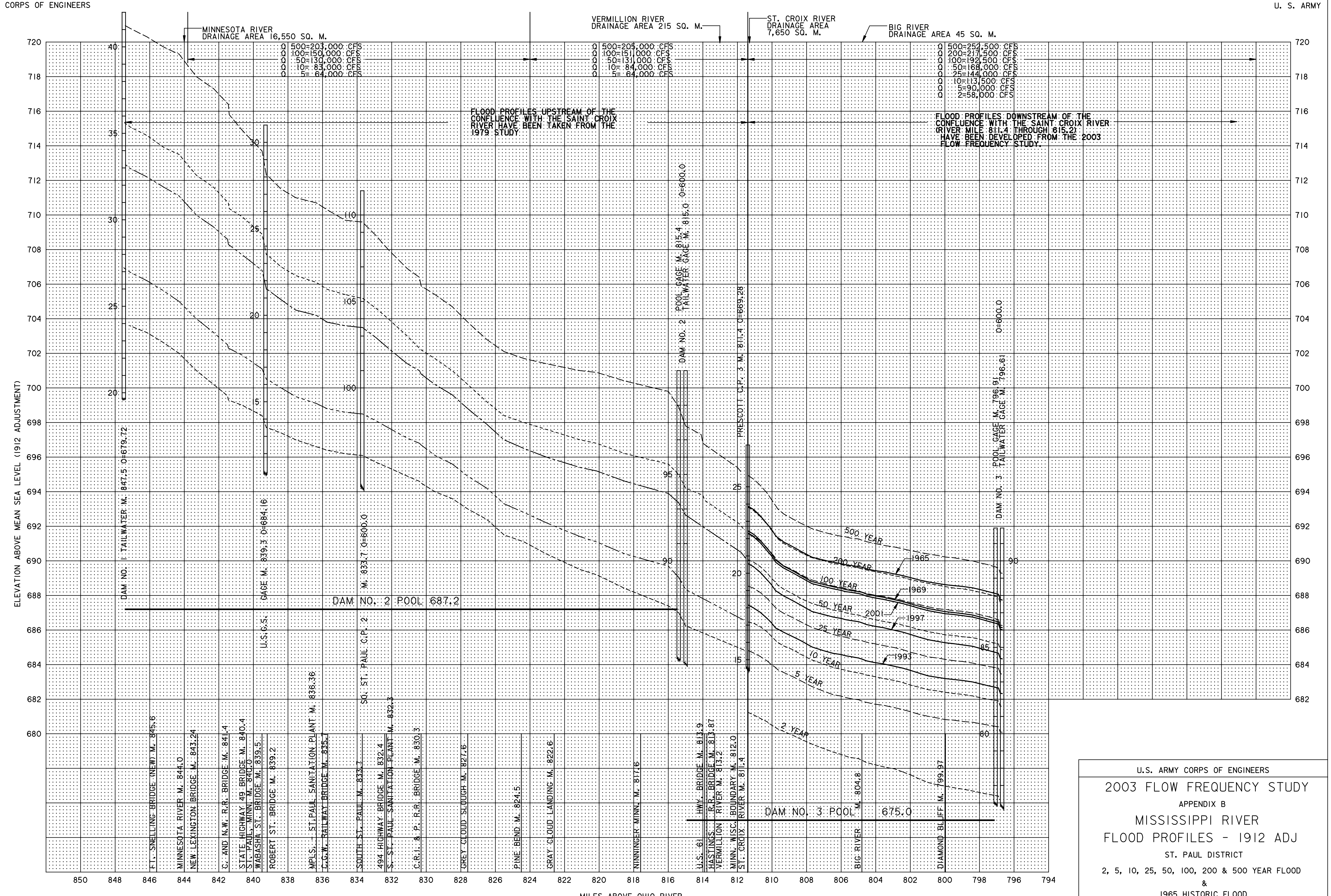
Michael Brindisi, who has been artis...

Conviction is upheld in restaurant threat case

By Margaret Zack
Staff Writer

CORPS OF ENGINEERS

U. S. ARMY



U.S. ARMY CORPS OF ENGINEERS

2003 FLOW FREQUENCY STUDY

APPENDIX B

MISSISSIPPI RIVER

FLOOD PROFILES - 1912 ADJ

ST. PAUL DISTRICT

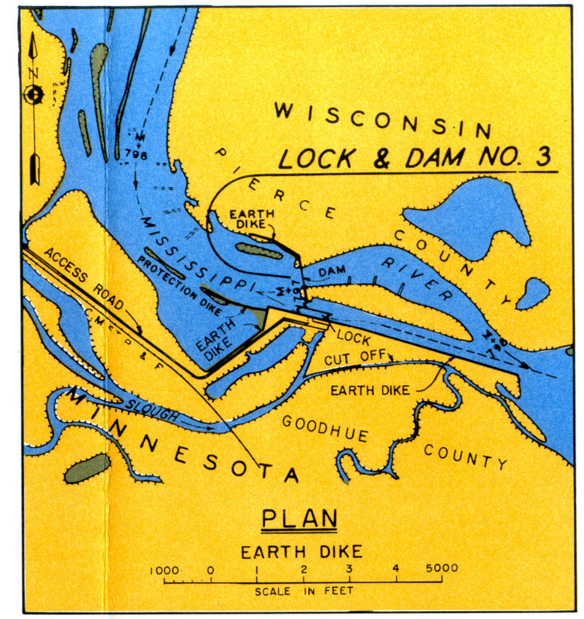
2, 5, 10, 25, 50, 100, 200 & 500 YEAR FLOOD

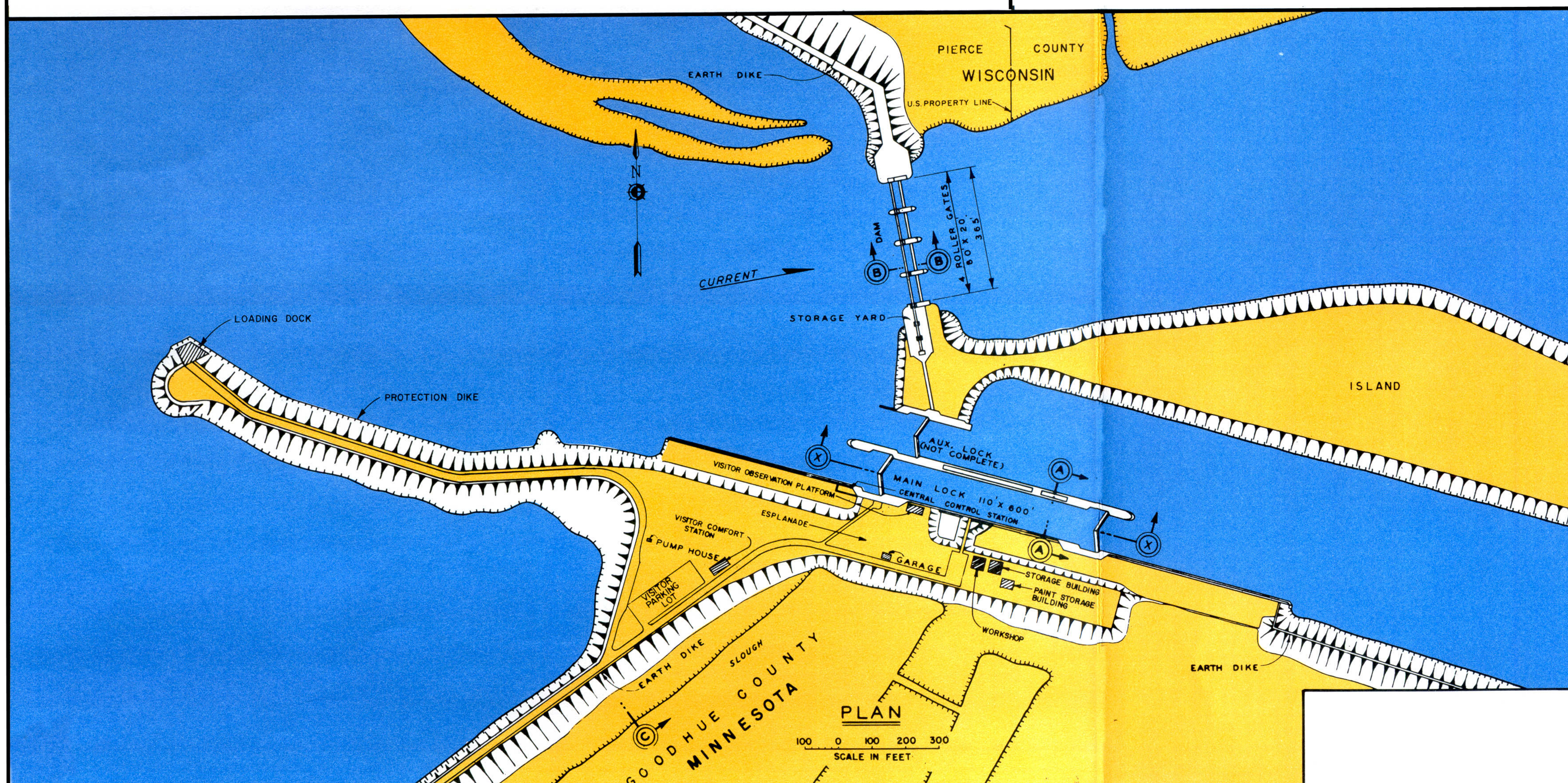
&

1965 HISTORIC FLOOD

RIVER MILES 796.8 TO 847.5

PLATE # 11





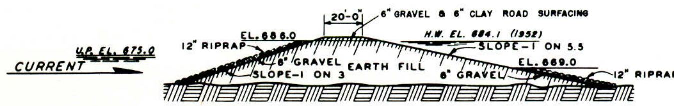
TOTAL LENGTH OF EARTH DIKE – 2607.0 FT.
DEPTH ON UPPER GATE SILL – 17.0 FT. (U.P. EL. 675.0)
DEPTH ON LOWER GATE SILL – 14.0 FT. (L.P. EL. 667.0)
ELEVATION UPPER GATE SILL – 658.0
ELEVATION LOWER GATE SILL – 653.0

ELEVATIONS ARE REFERRED TO M.S.L. (1912 ADJ.)

Upper Mississippi River
Nine-Foot Navigation Project

Lock and Dam No. 3
Project Location Map

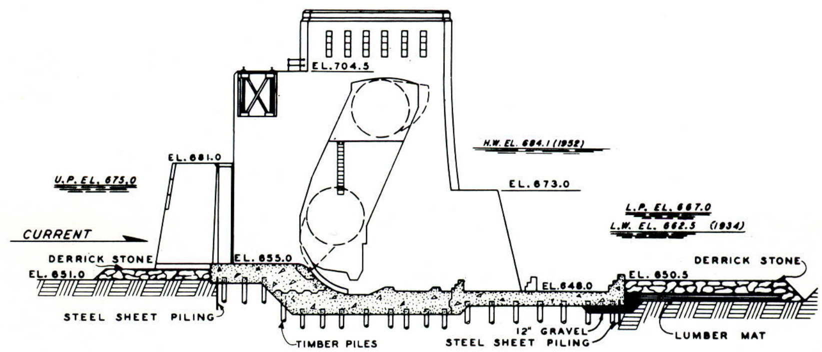
US Army Corps of Engineers
St. Paul District - 30 Sept 1992



SECTION C-C

EARTH DIKE

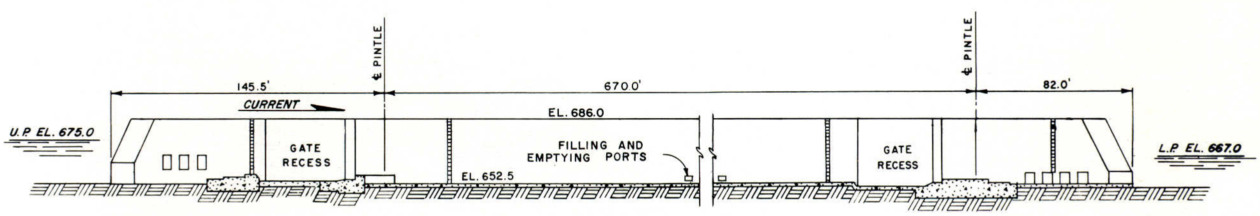
20 0 20 40 60
SCALE IN FEET



SECTION B-B

ROLLER GATE

10 0 10 20 30
SCALE IN FEET

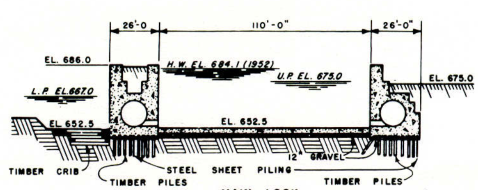


SECTION X-X

MAIN LOCK

20 0 20 40 60
SCALE IN FEET

ELEVATIONS ARE REFERRED TO M.S.L. (1912 ADJ.)



SECTION A-A

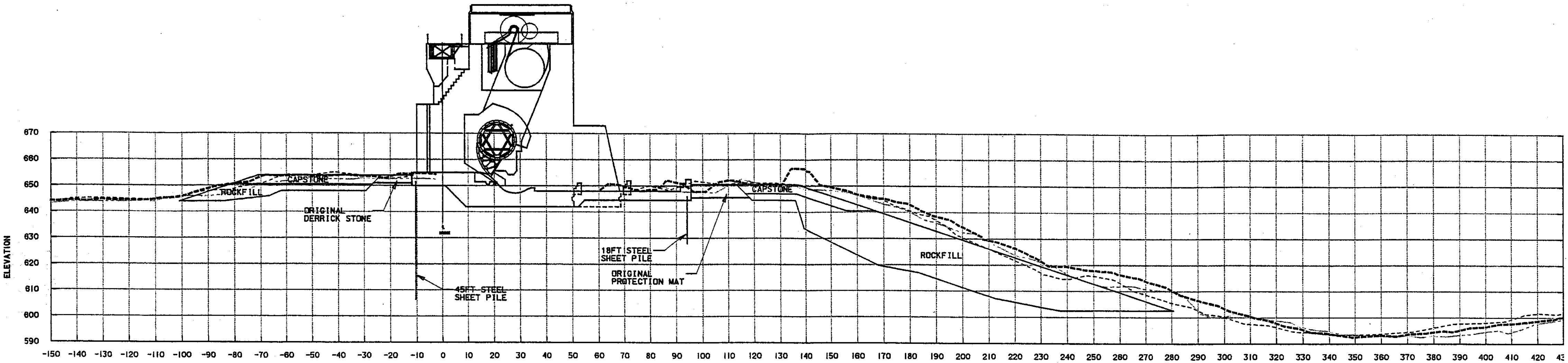
LOCK

20 0 20 40 60
SCALE IN FEET

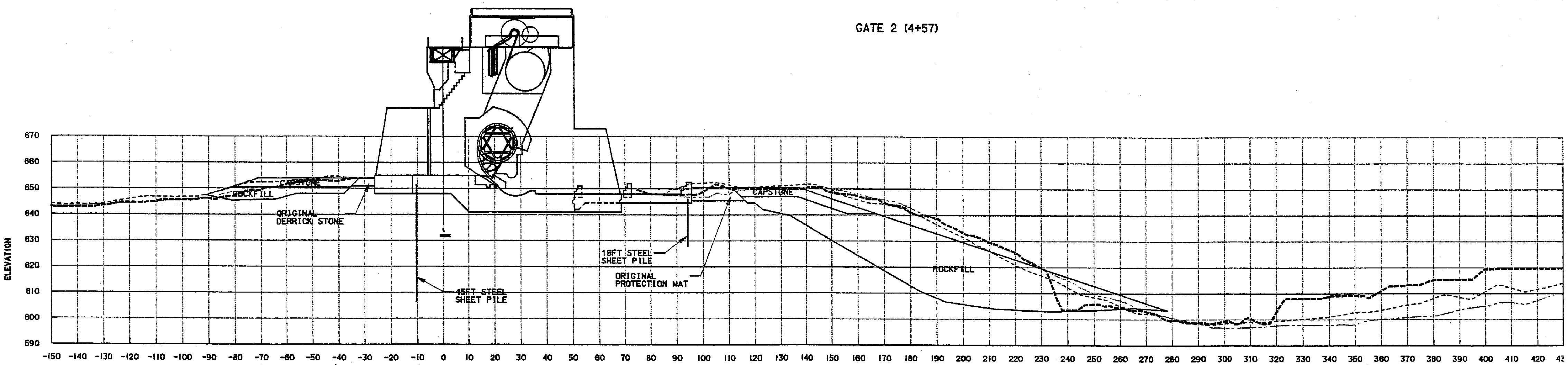
Upper Mississippi River
Nine-Foot Navigation Project

Lock and Dam No. 3
Cross Sections

US Army Corps of Engineers
St. Paul District - 30 Sept 1977



GATE 2 (4+57)



PIER 2 (4+10)

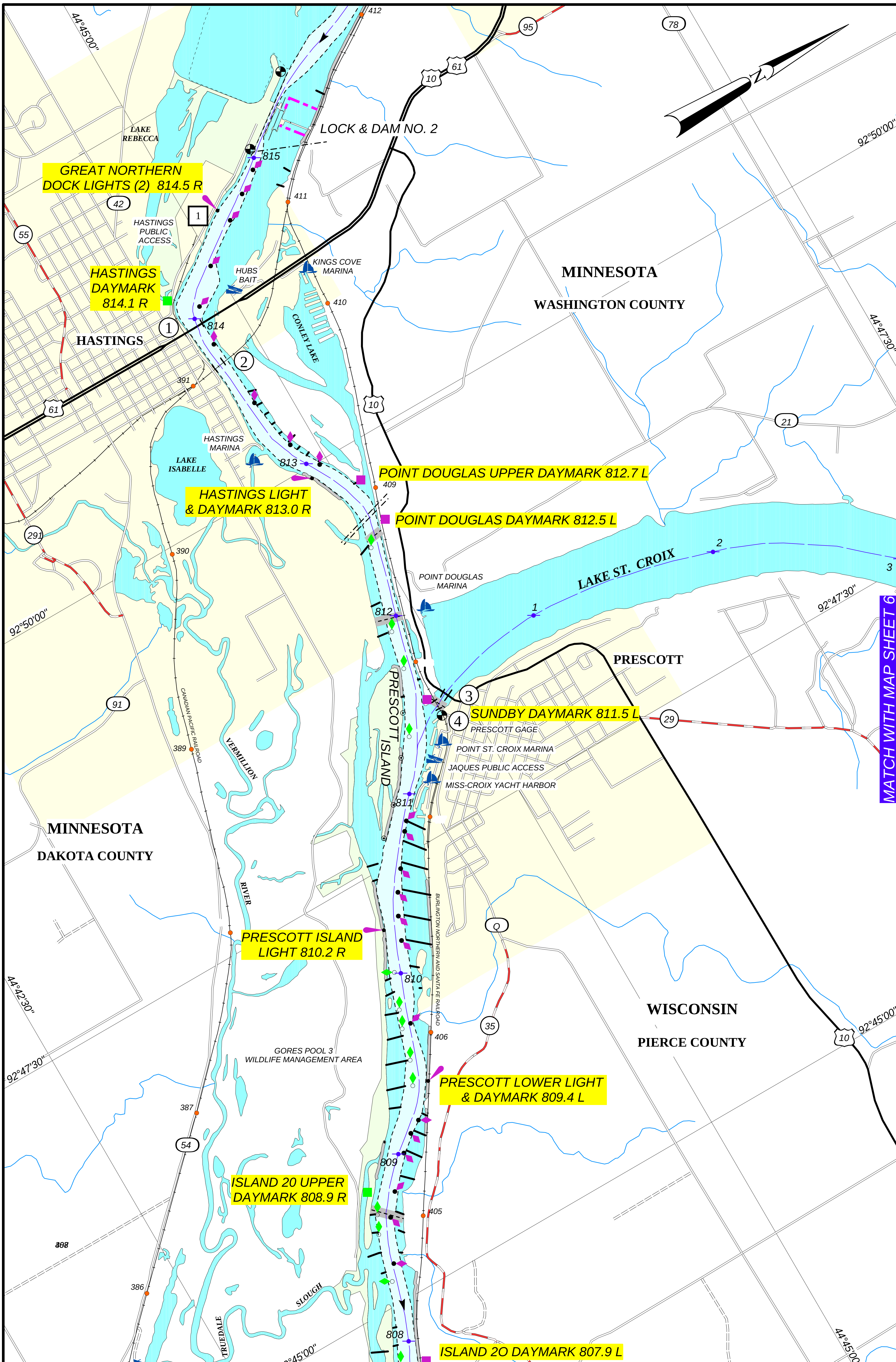
KEY

2001
2000
1999

Upper Mississippi River
Nine-Foot Navigation Project

Scour Protection
Upstream and Downstream of Dam
Riprap and Rockfill Placed in 1983

U.S. Army Corps of Engineers
St. Paul District – St. Paul, MN



2001

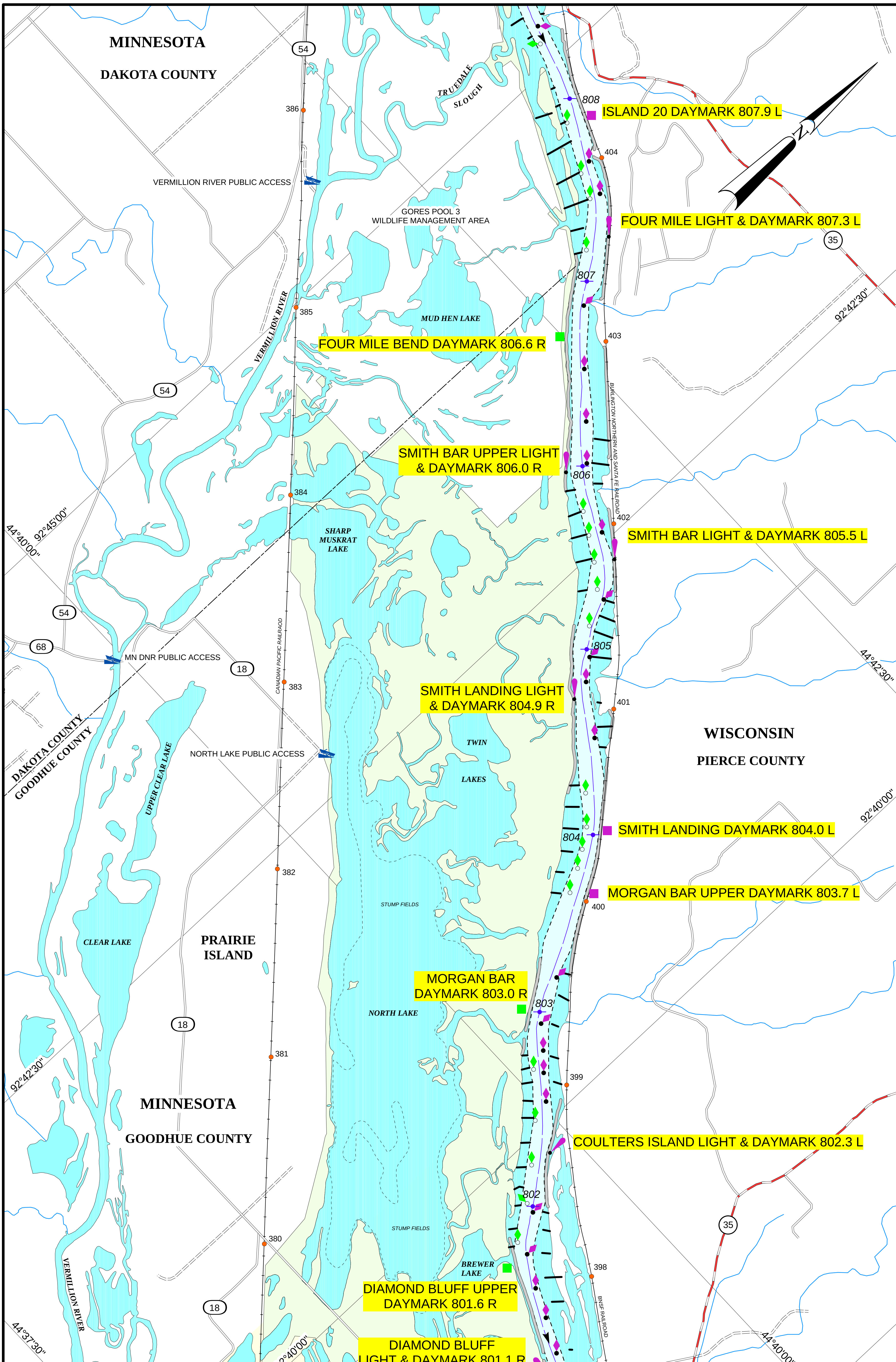
BUOY POSITIONS ON CHARTS ARE APPROXIMATE, SEE NOTICE ON LEGEND NO. 1

SCALE 1:31,680
1 INCH = 1/2 MILE

1 0.5 0 1 MILES

1 0.5 0 1 KILOMETERS

Upper Mississippi River
Nine-Foot Channel Navigation Project
Navigation Chart
River Mile 808 to 816
U.S. Army Corps of Engineers
St. Paul District - St. Paul, MN



2001

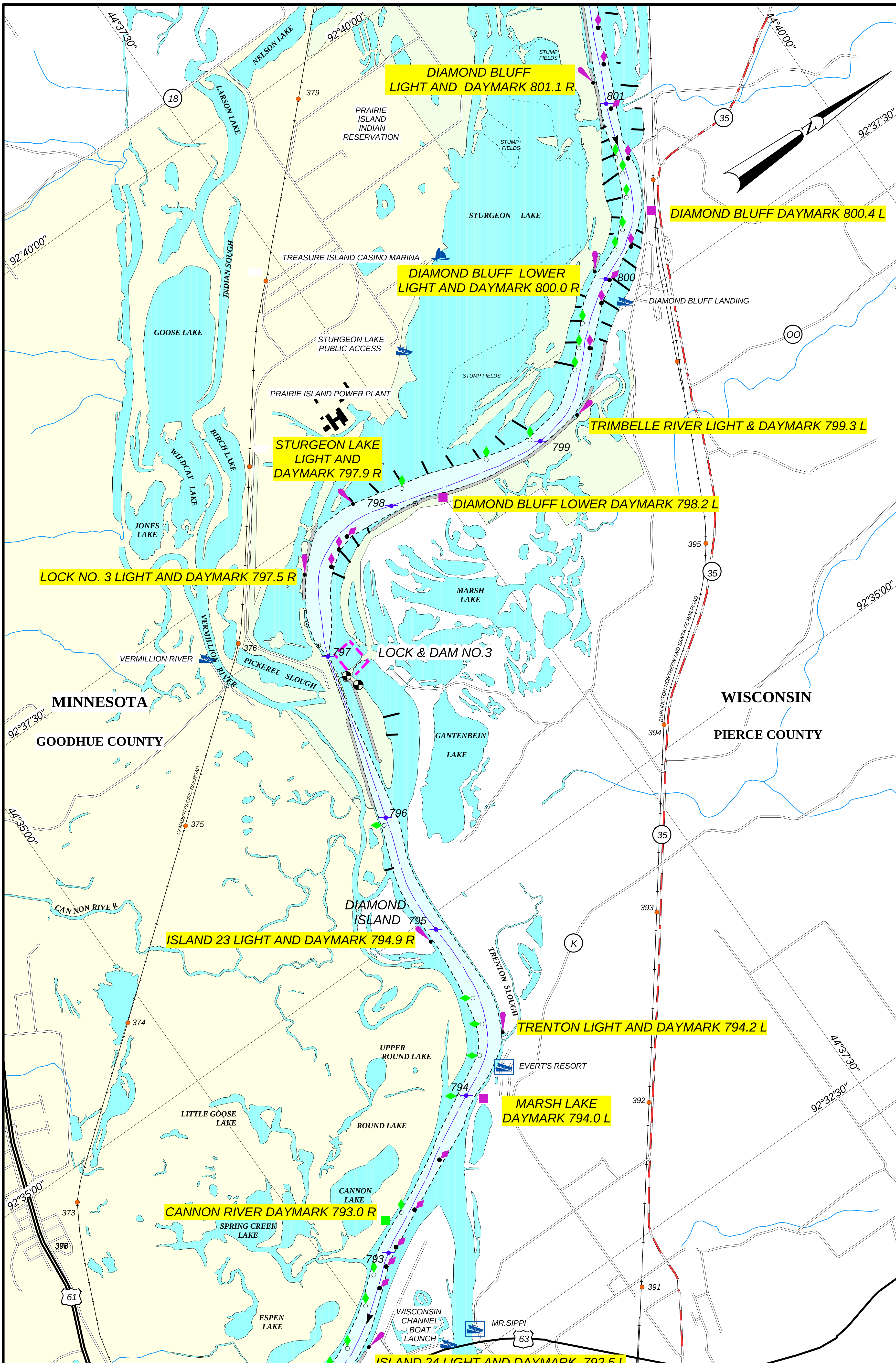
BUOY POSITIONS ON CHARTS ARE APPROXIMATE, SEE NOTICE ON LEGEND NO. 1

SCALE 1:31,680
1 INCH = 1/2 MILE

1 0.5 0 1 MILES

1 0.5 0 1 KILOMETERS

Upper Mississippi River
Nine-Foot Channel Navigation Project
Navigation Chart
River Mile 802 to 808
U.S. Army Corps of Engineers
St. Paul District - St. Paul, MN



2001

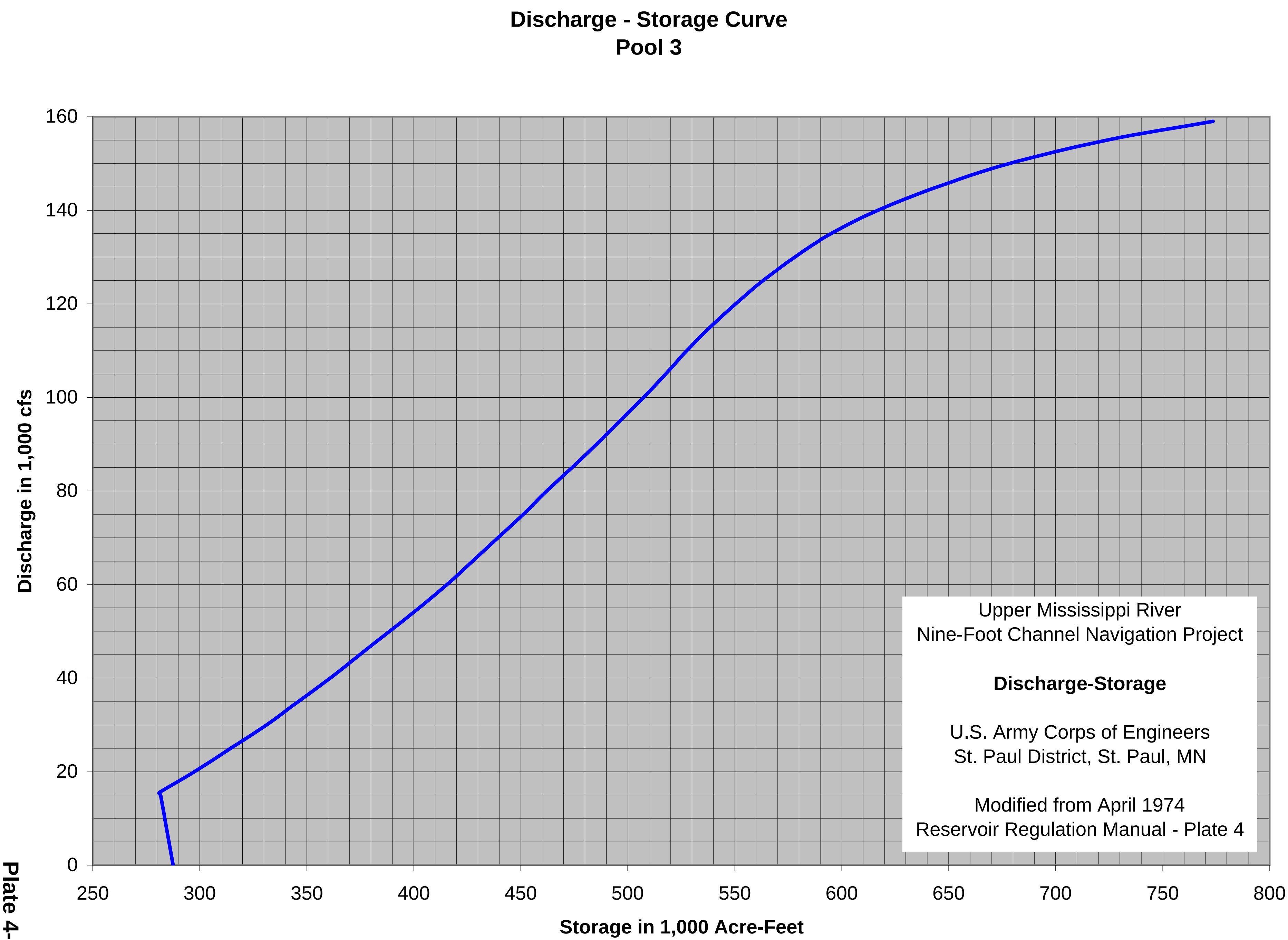
BUOY POSITIONS ON CHARTS ARE APPOXIMATE, SEE NOTICE ON LEGEND NO. 1

SCALE 1:31,680
1 INCH = 1/2 MILE

1 0.5 0 1 MILES

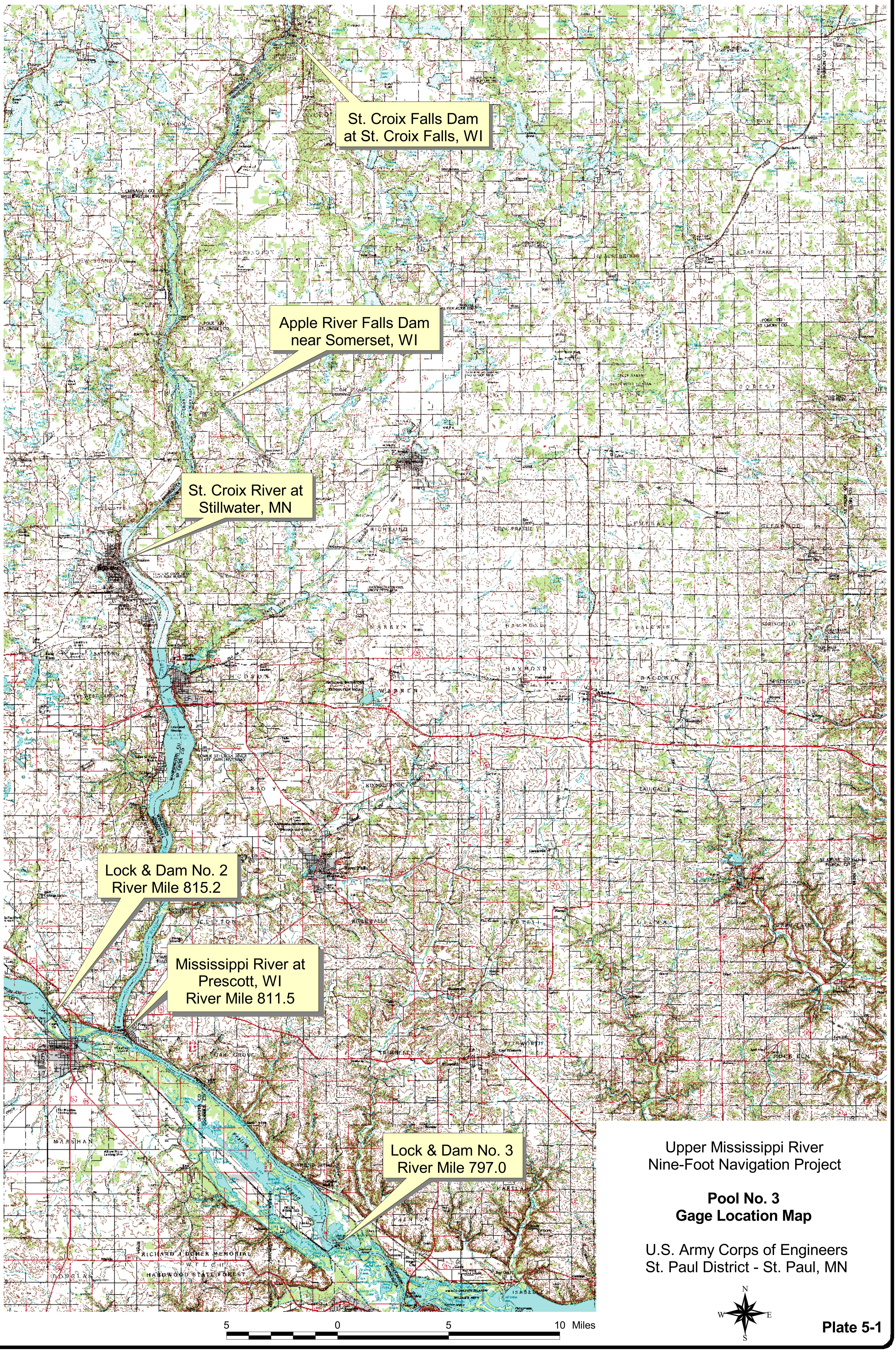
1 0.5 0 1 KILOMETERS

Upper Mississippi River
Nine-Foot Channel Navigation Project
Navigation Chart
River Mile 793 to 801
U.S. Army Corps of Engineers
St. Paul District - St. Paul, MN



Discharge - Storage Curve
Pool 3
Discharge in 1,000 cfs
160
140
120
100
80
60
40
20
0
250
300
350
400
450
500
550
600
650
700
750
800
Storage in 1,000 Acre-Feet
Upper Mississippi River
Nine-Foot Channel Navigation Project
Discharge-Storage
U.S. Army Corps of Engineers
St. Paul District, St. Paul, MN
Modified from April 1974
Reservoir Regulation Manual - Plate 4

Plate 4-1



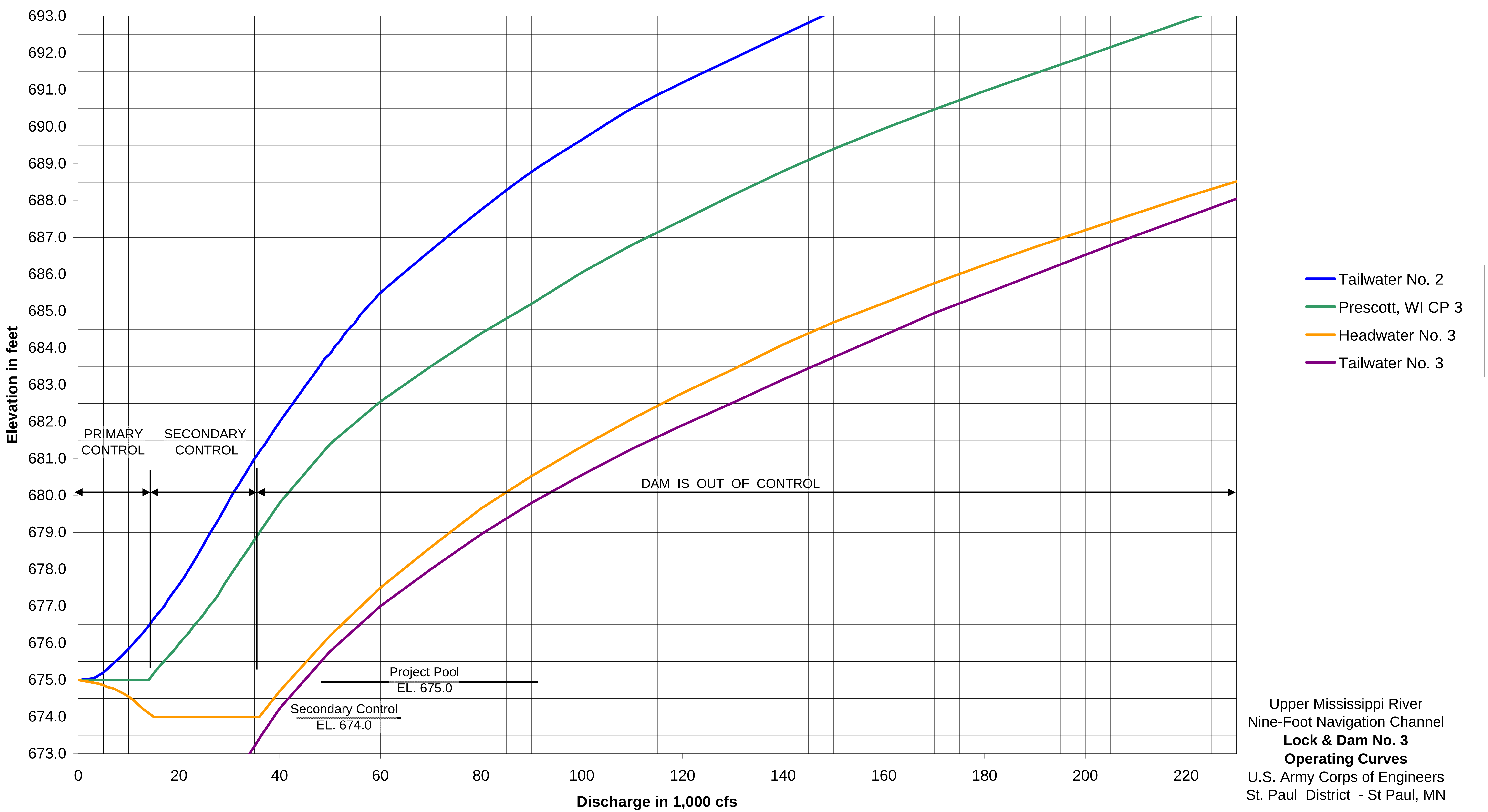
Upper Mississippi River
Nine-Foot Navigation Project

Pool No. 3
Gage Location Map

U.S. Army Corps of Engineers
St. Paul District - St. Paul, MN

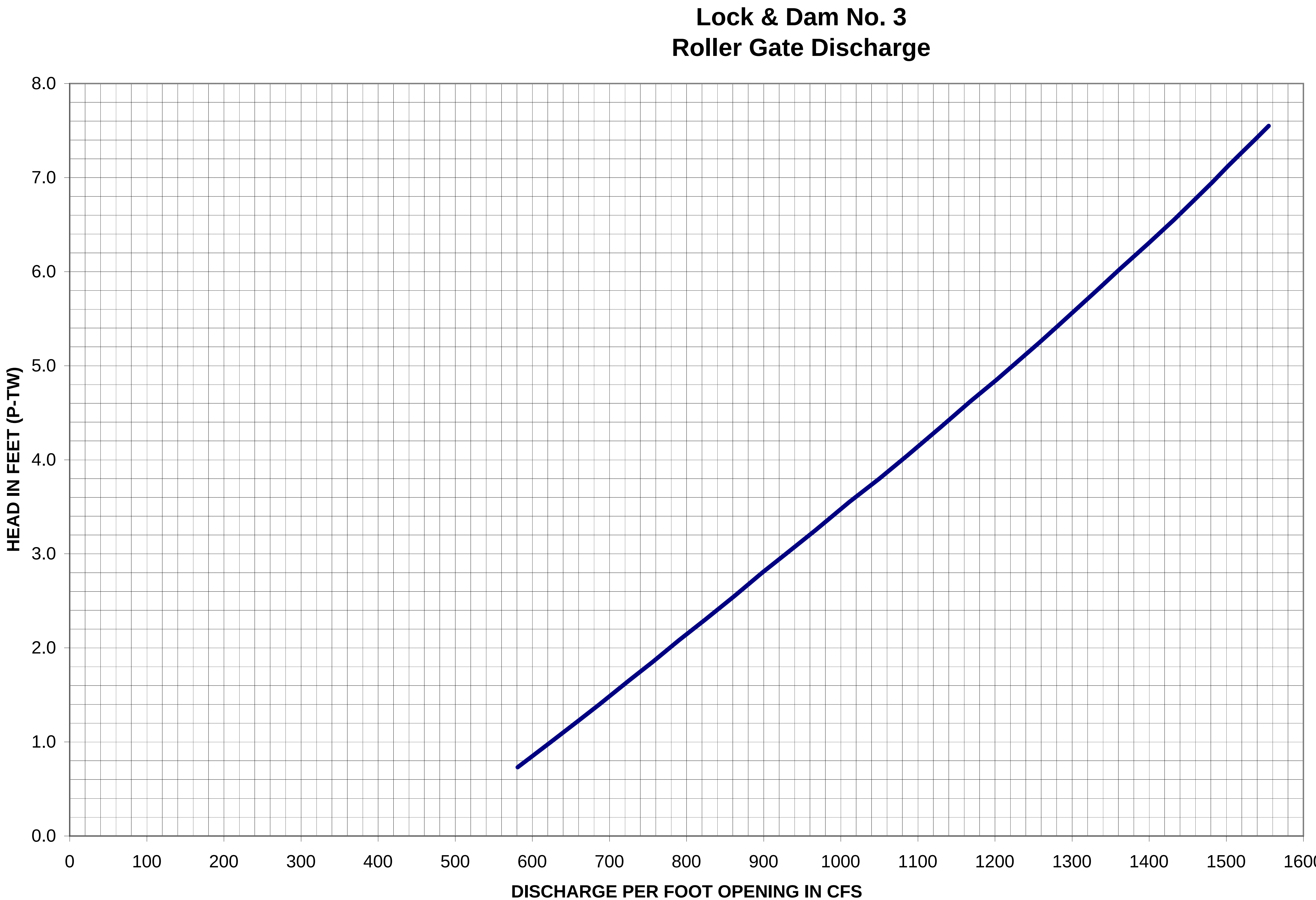
Plate 5-1

LOCK & DAM NO. 3 OPERATING CURVES



Upper Mississippi River
Nine-Foot Navigation Channel
Lock & Dam No. 3
Operating Curves
U.S. Army Corps of Engineers
St. Paul District - St Paul, MN

Plate 7-1



Upper Mississippi River
Nine-Foot Channel Navigation Project

Lock & Dam No. 3
Roller
Gate Discharge

U.S. Army Corps of Engineers
St. Paul District - St. Paul, MN
June 2003

Plate 7-2