HYDRAULIC CONNECTIVITY (HC) ENGINEERING & HYDRAULICS PERSPECTIVES

Presented at the UMRR HREP Team Meeting
September 28, 2016

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Upper Mississippi River Restoration
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Measuring HC is a High Priority Because:

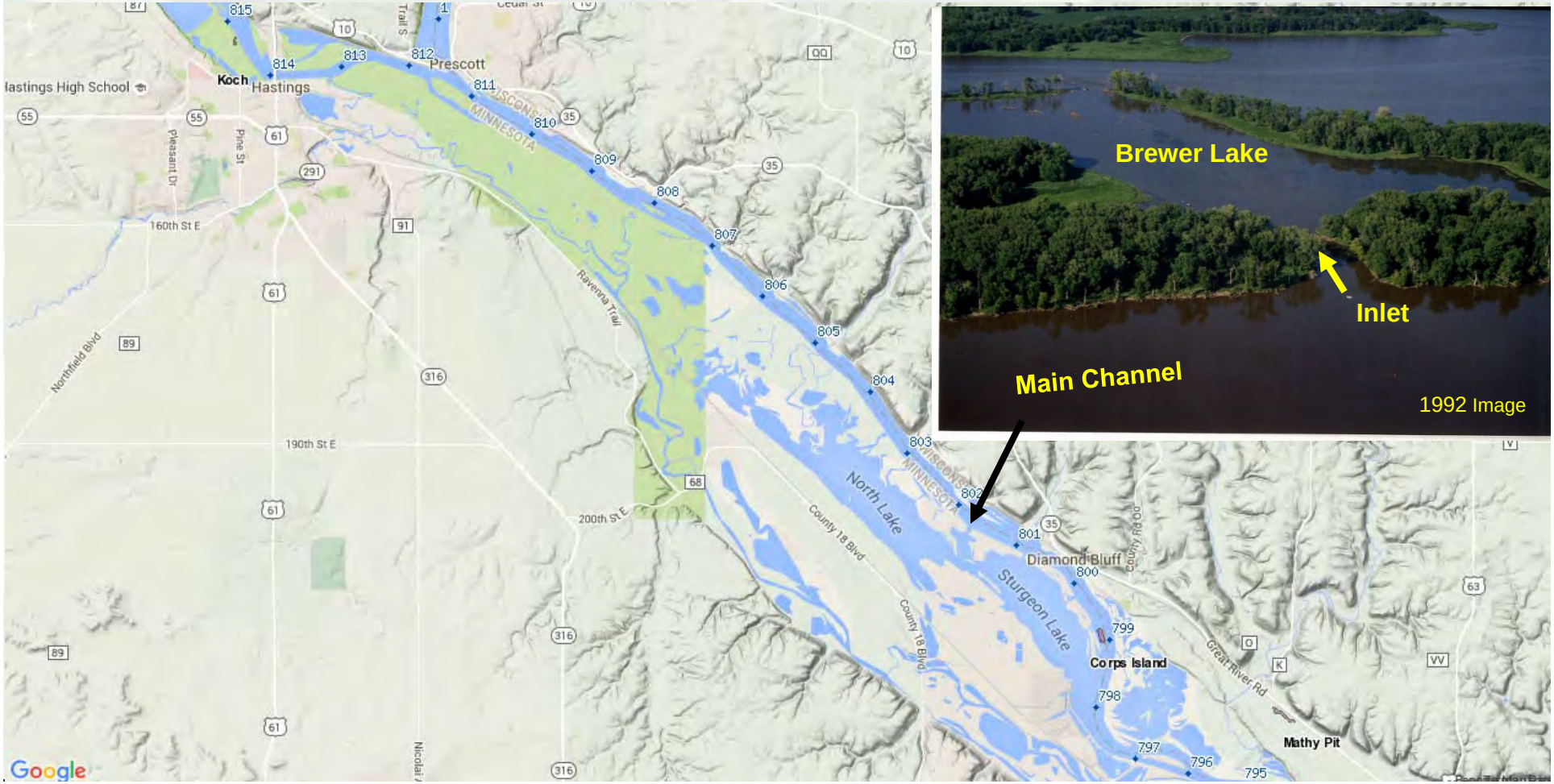
- HC is extremely high in many reaches of the St. Paul District
- Projects in these reaches are designed to decrease channel to off-channel HC
- Dredge cut location is strongly affected by HC
- Sediment deposition in backwaters increases with increasing HC
- Nutrient loads and processing is strongly affected by HC
- Hydraulic models require extensive calibration for HC.

Hydraulic Surveys

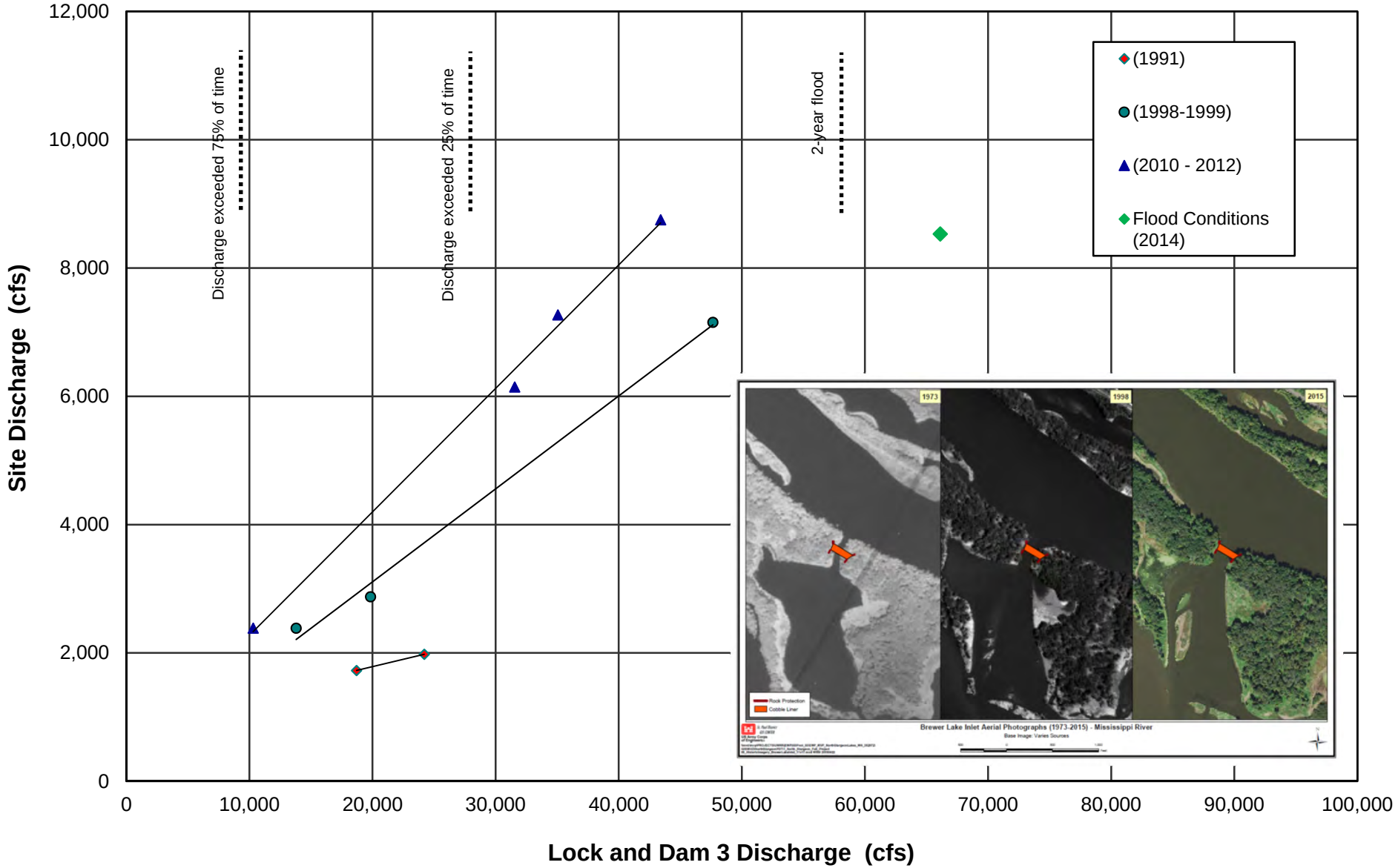
Best practices encourage a minimum of four high quality transects be collected that agree with each other to within 5% of the mean of all the samples.

WinRiver II Users Manual

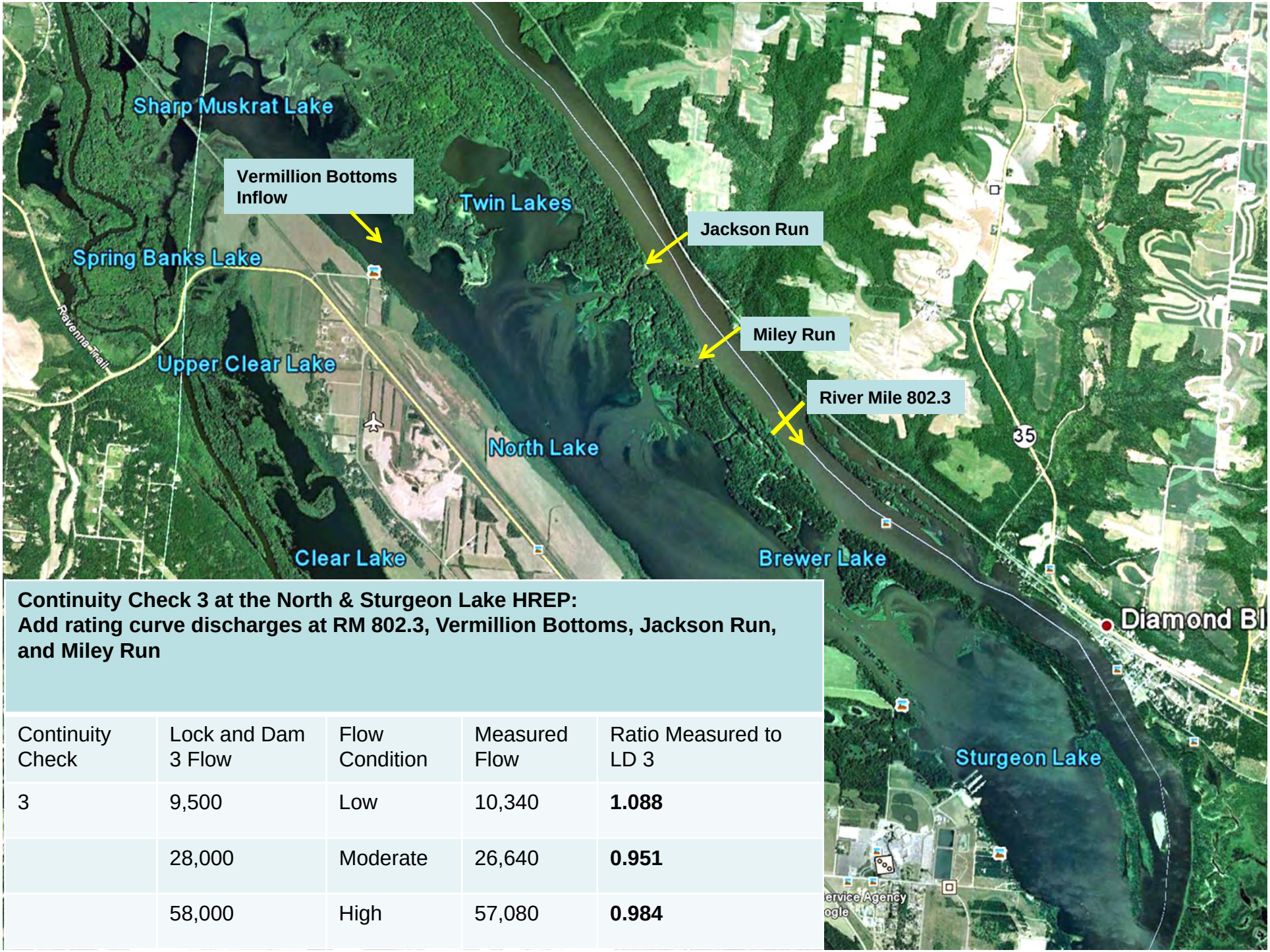
Rating Curves of Site Discharge vs Total River Discharge are Developed



Mississippi River - Pool 3
RM 801.70 SW (800') - Brewer Lake Inlet



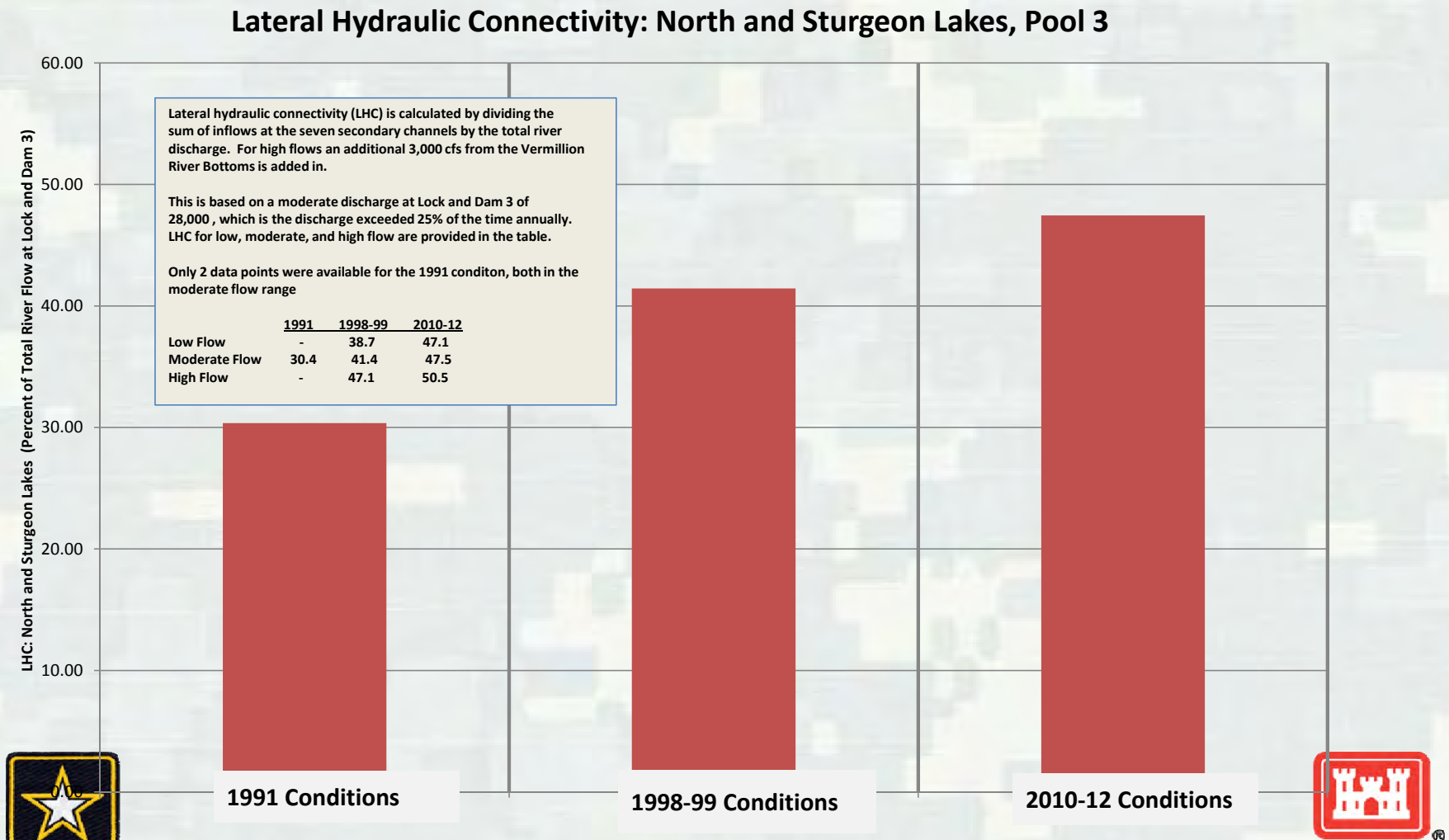
PRIMARY CONTROL	SECONDARY CONTROL	GATES OUT OF WATER

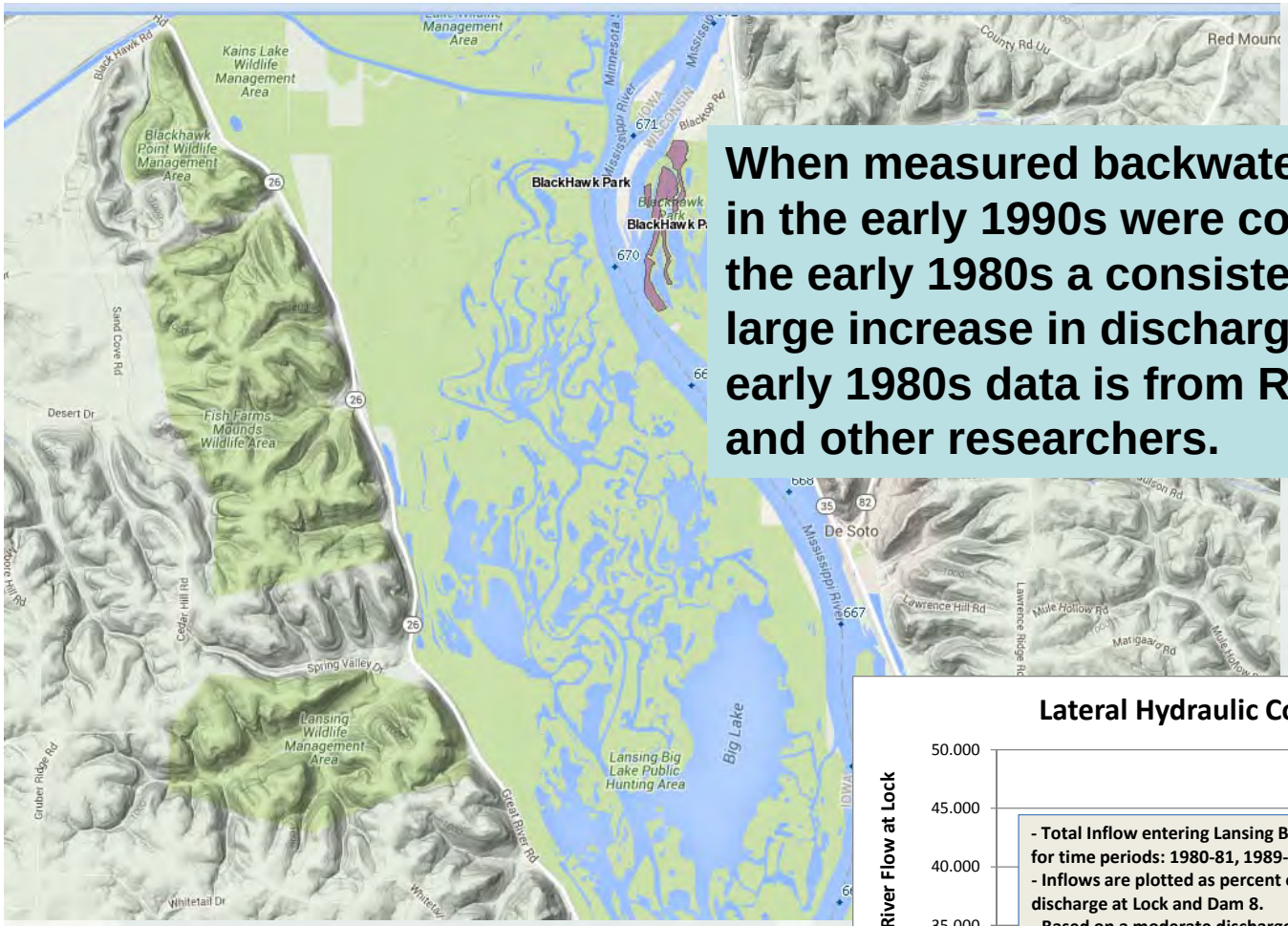


Continuity Check 3 at the North & Sturgeon Lake HREP:
Add rating curve discharges at RM 802.3, Vermillion Bottoms, Jackson Run, and Miley Run

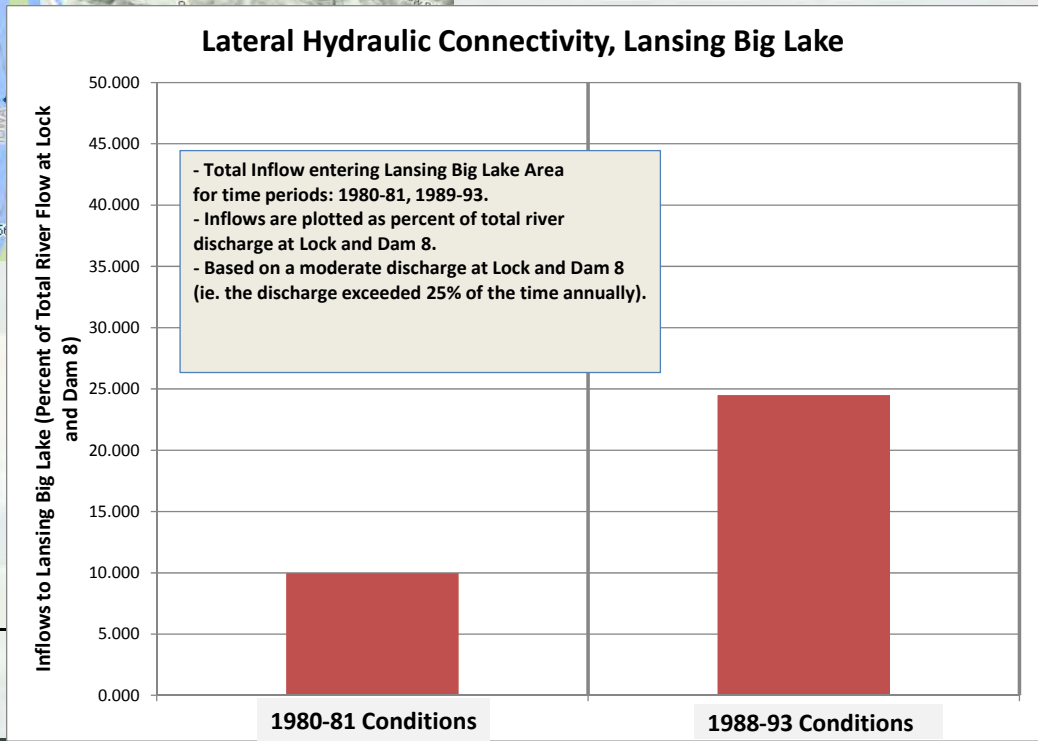
Continuity Check	Lock and Dam 3 Flow	Flow Condition	Measured Flow	Ratio Measured to LD 3
3	9,500	Low	10,340	**1.088**
	28,000	Moderate	26,640	**0.951**
	58,000	High	57,080	**0.984**

HC to North and Sturgeon Lakes increased from 30% to 47% of the total river flow over the last couple of decades.





When measured backwater discharges obtained in the early 1990s were compared to those from the early 1980s a consistent and sometimes large increase in discharge was observed. The early 1980s data is from Rada, Eckblad, Fremling, and other researchers.



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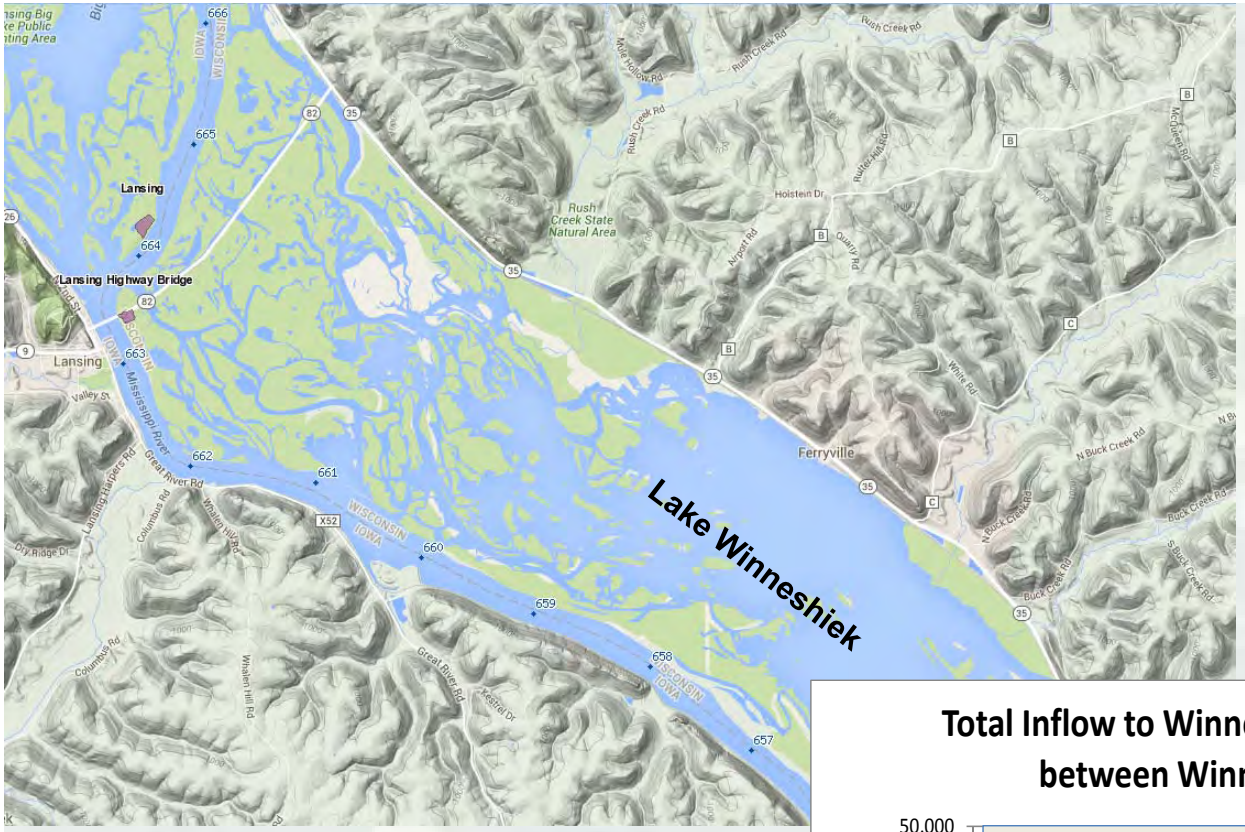
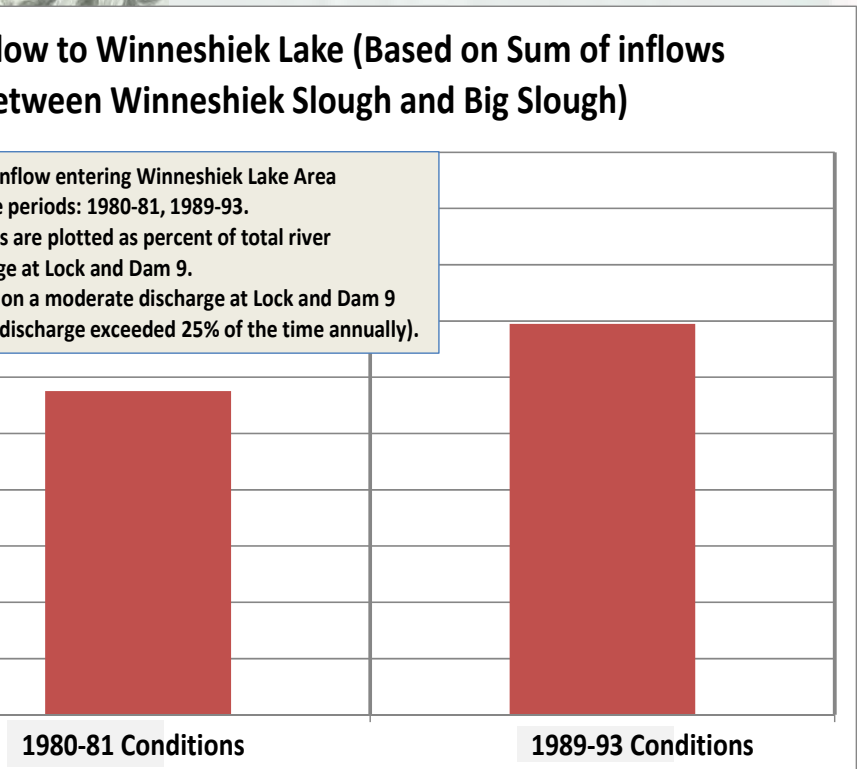

Lansing
Lansing Highway Bridge
Lansing
Rush Creek State Natural Area
Ferryville
Lake Winneshiek
WISCONSIN
IOWA
Mississippi River
Great River Rd
Columbus Rd
Whalen Hill Rd
Valley St
Dry Ridge Dr
Lansing Ramsey Rd
Rush Creek Rd
Mule Hollow Rd
Hoistein Dr
Rutter Mill Rd
Airport Rd
Quarry Rd
White Rd
McQuoid Rd
N Buck Creek Rd
Buck Creek Rd
S Buck Creek Rd
Kestrel Dr
665
664
663
662
661
660
659
658
657
666
X52
82
35
9
B
C


Total Inflow to Winneshiek Lake (Based on Sum of inflows between Winneshiek Slough and Big Slough)
- Total Inflow entering Winneshiek Lake Area for time periods: 1980-81, 1989-93.
- Inflows are plotted as percent of total river discharge at Lock and Dam 9.
- Based on a moderate discharge at Lock and Dam 9 (ie. the discharge exceeded 25% of the time annually).
Inflows to Wineshiek Lake (Percent of Total River Flow at Lock and Dam 8)
50.000
45.000
40.000
35.000
30.000
25.000
20.000
15.000
10.000
5.000
0.000
1980-81 Conditions
1989-93 Conditions

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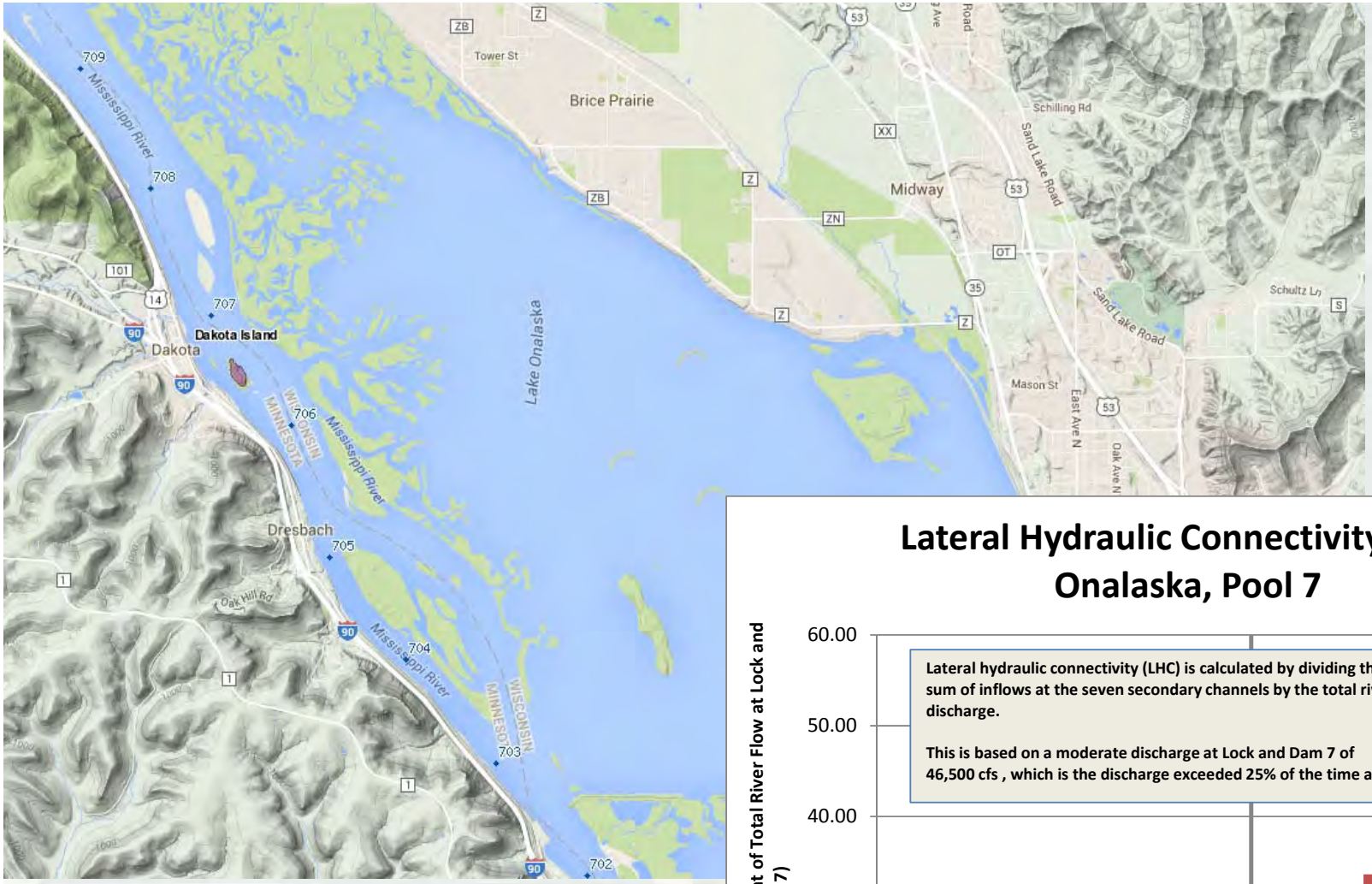
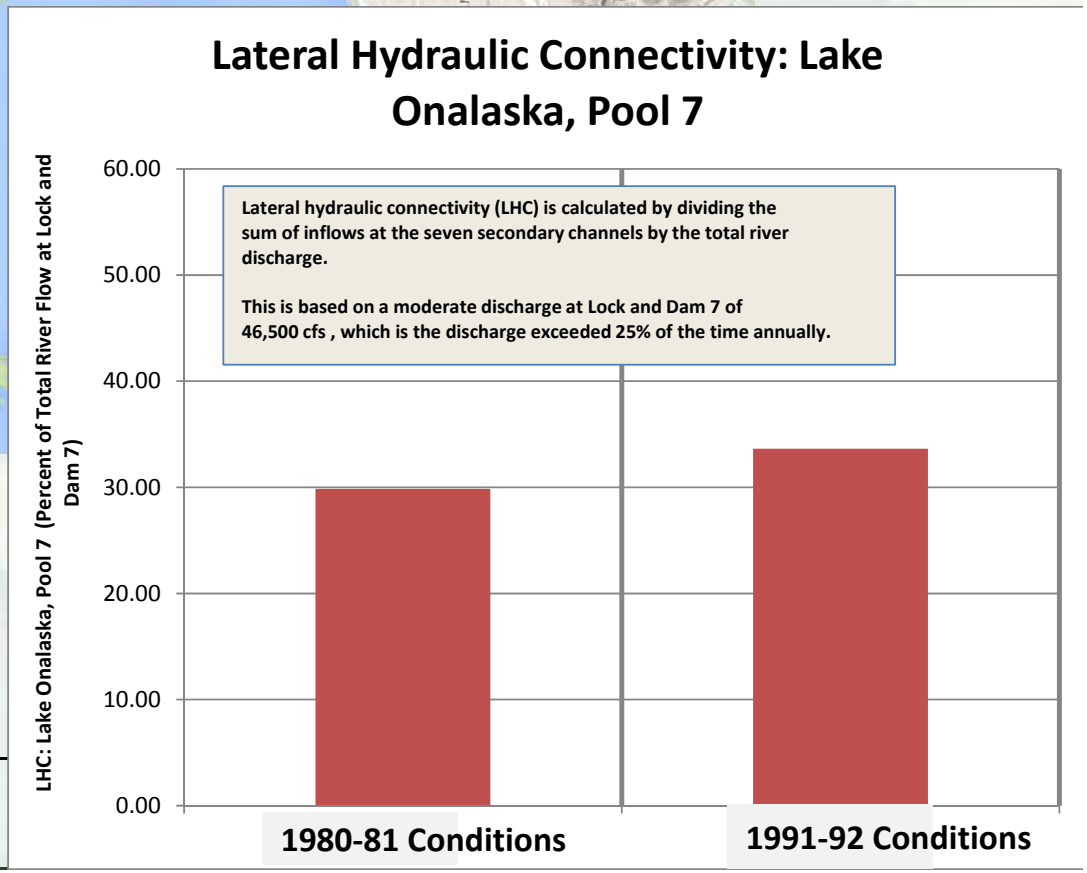

Brice Prairie
Midway
Dakota Island
Dakota
Dresbach
Lake Onalaska
Mississippi River
Tower St
Schilling Rd
Sand Lake Road
Mason St
East Ave N
Schultz Ln
Oak Hill Rd
WISCONSIN
MINNESOTA
709
708
707
706
705
704
703
702


Lateral Hydraulic Connectivity: Lake Onalaska, Pool 7
LHC: Lake Onalaska, Pool 7 (Percent of Total River Flow at Lock and Dam 7)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Lateral hydraulic connectivity (LHC) is calculated by dividing the sum of inflows at the seven secondary channels by the total river discharge.
This is based on a moderate discharge at Lock and Dam 7 of 46,500 cfs , which is the discharge exceeded 25% of the time annually.
1980-81 Conditions
1991-92 Conditions

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Because of observed or measured increases in discharge, project features tended to focus on reducing hydraulic connectivity.

Pool 8 Phase II Area Recommended Plan

Large barrier islands to reduce velocities and sediment inflow

Rock sills to allow floodplain conveyance during floods

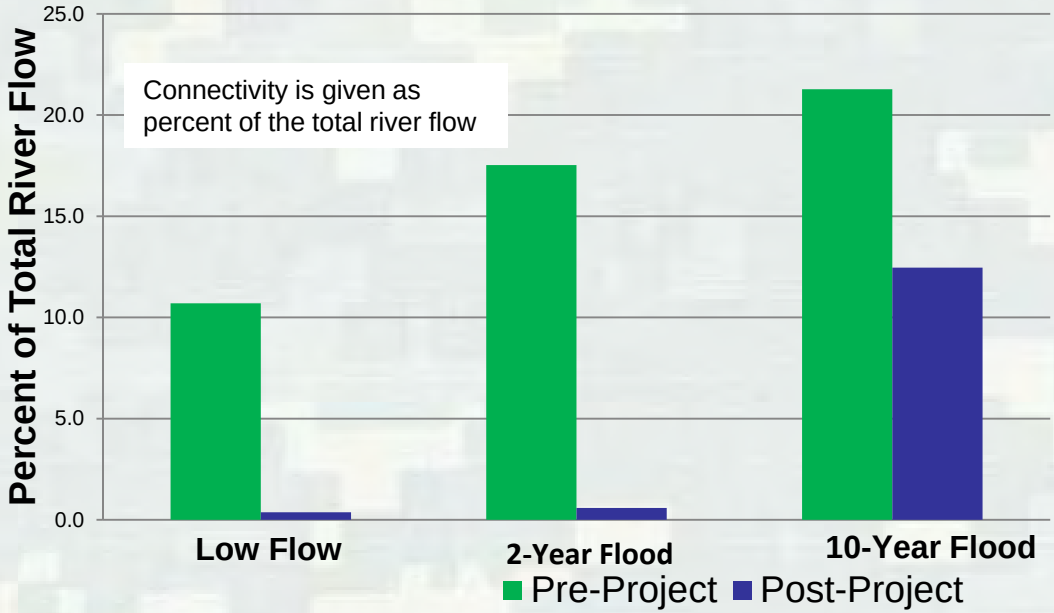
A small low flow notch is included in the upper sill

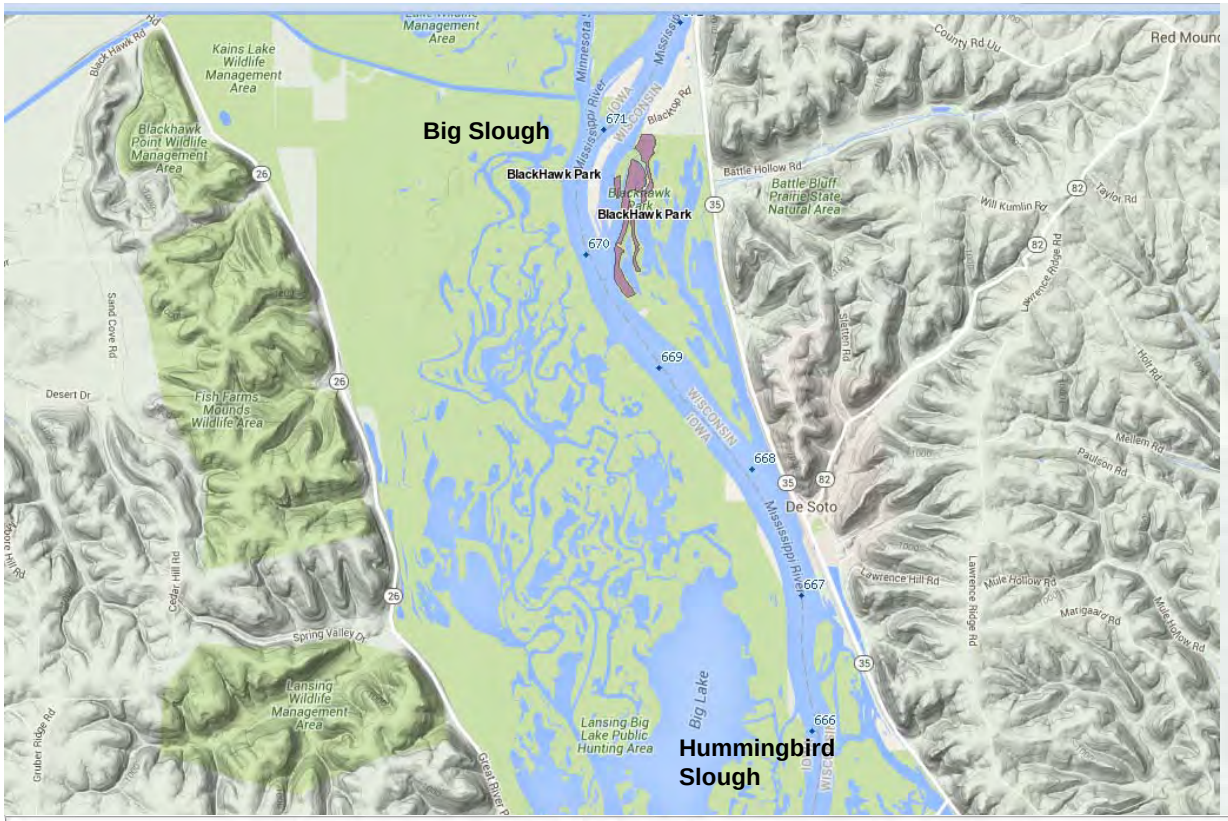
Interior Islands to reduce wind fetch and to force water to flow through the channels promoting scour

Backwater dredging

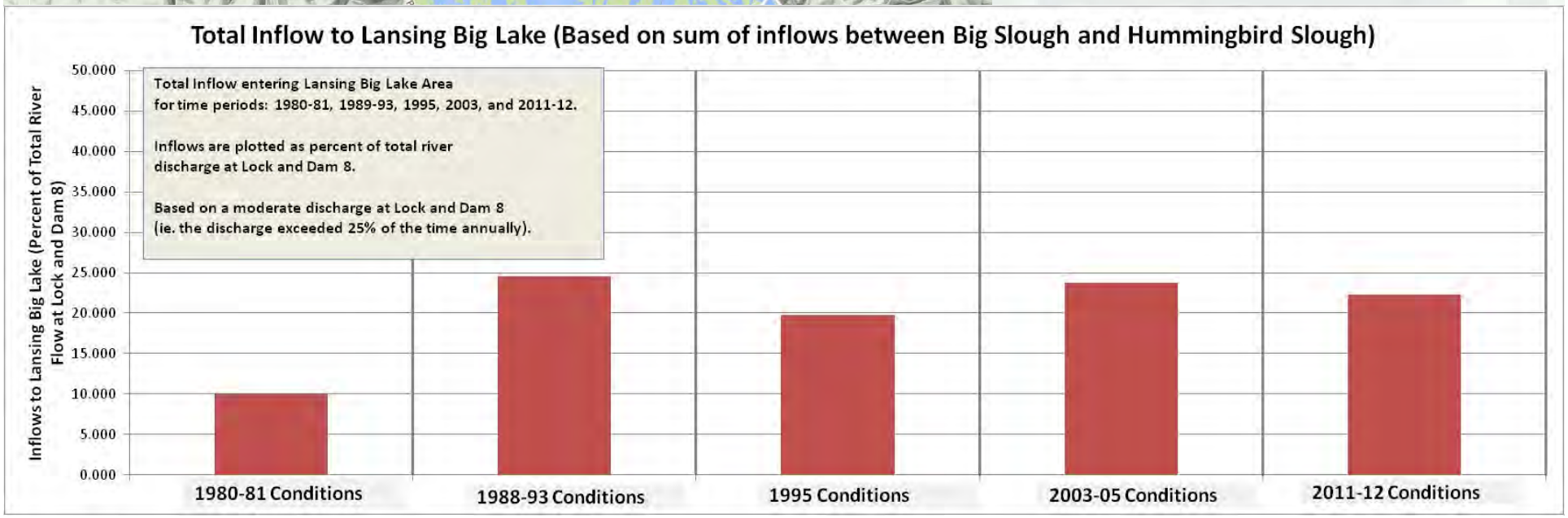
Hydraulic Connectivity in the Phase II Area was restored to a condition that helped meet criteria and achieve objectives.

For post-project conditions the seasonal variation in hydrologic connectivity was increased significantly with low connectivity for low flow to bankfull conditions and then increasing connectivity for floods.



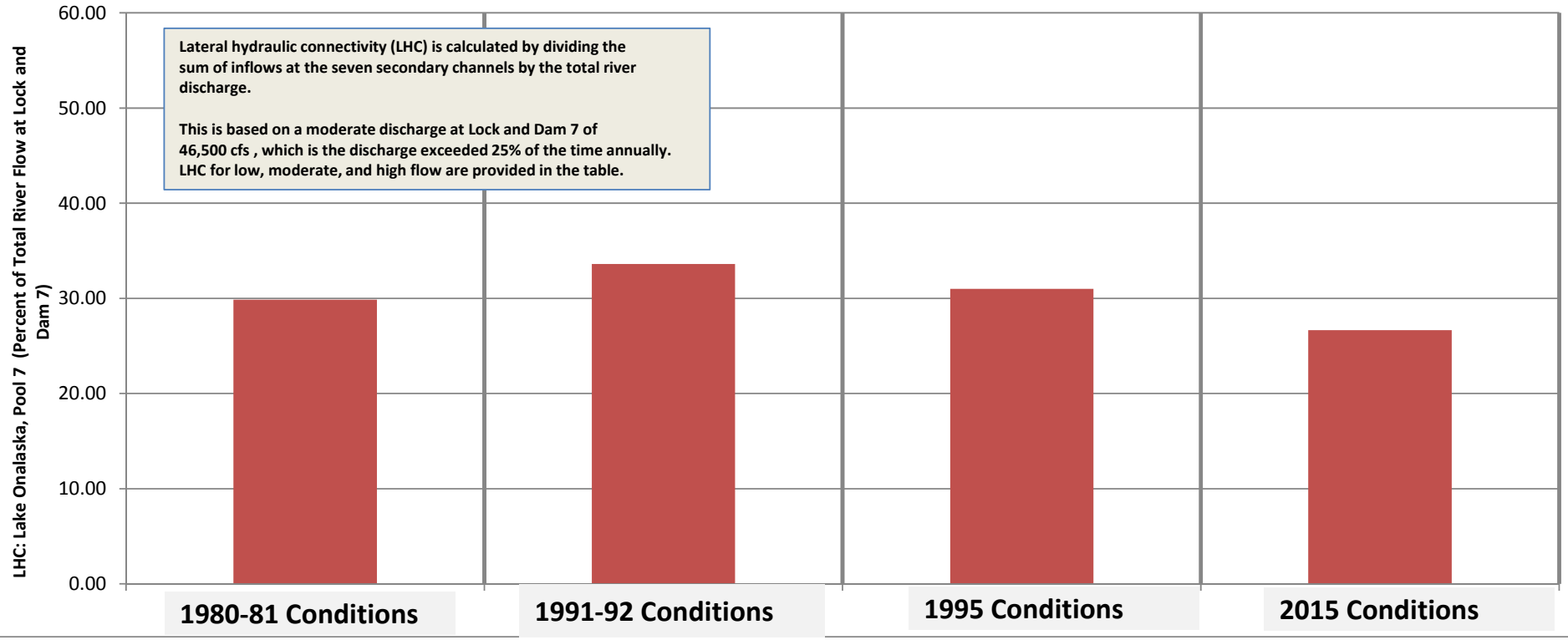


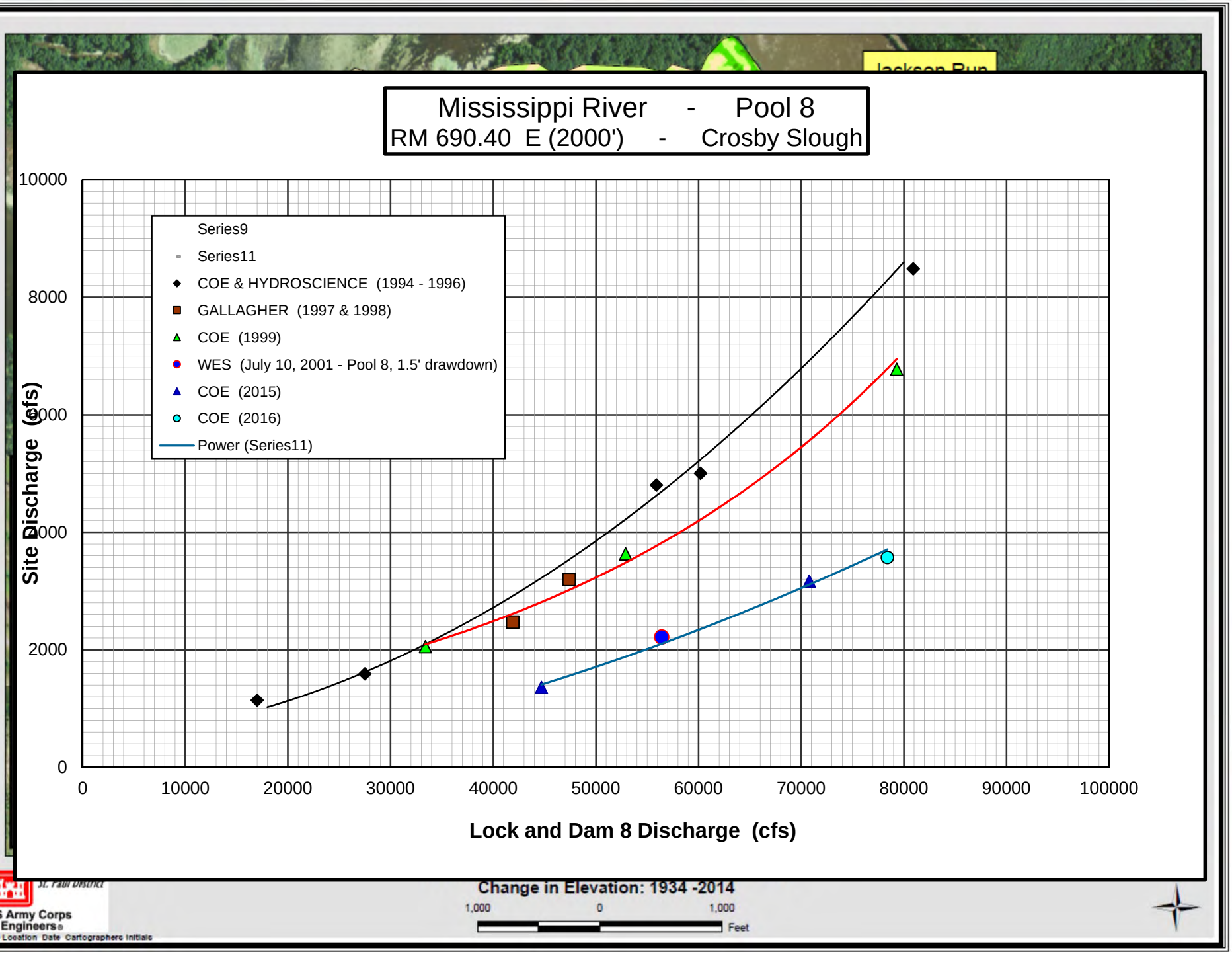
The Lansing Big Lake project was constructed in 1994



The Dakota Navigation project was constructed in 1994

Lateral Hydraulic Connectivity: Lake Onalaska, Pool 7



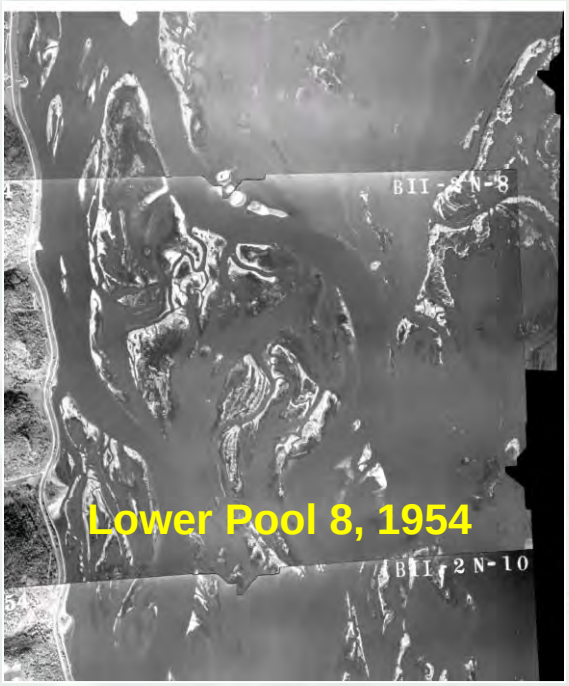

Mississippi River - Pool 8
RM 690.40 E (2000') - Crosby Slough
Site Discharge (cfs)
Lock and Dam 8 Discharge (cfs)
Series9
Series11
COE & HYDROSCIENCE (1994 - 1996)
GALLAGHER (1997 & 1998)
COE (1999)
WES (July 10, 2001 - Pool 8, 1.5' drawdown)
COE (2015)
COE (2016)
Power (Series11)
0
2000
4000
6000
8000
10000
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
100000
Change in Elevation: 1934 -2014
1,000
0
1,000
Feet
US Army Corps of Engineers
St. Paul District
File Location Date Cartographers Initials

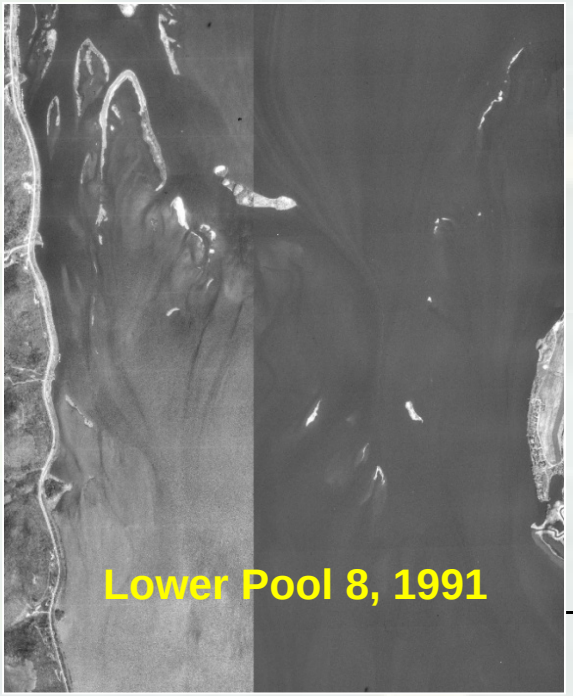
Summary

- Hydraulic connectivity between channels and off-channel areas is high throughout the St. Paul District and appeared to be increasing in the 1980s.
- Because of this UMRR projects were designed to reduce HC.
- Recent measurements suggest that flow into some backwaters has been stable or is decreasing.

Some Discussion Points

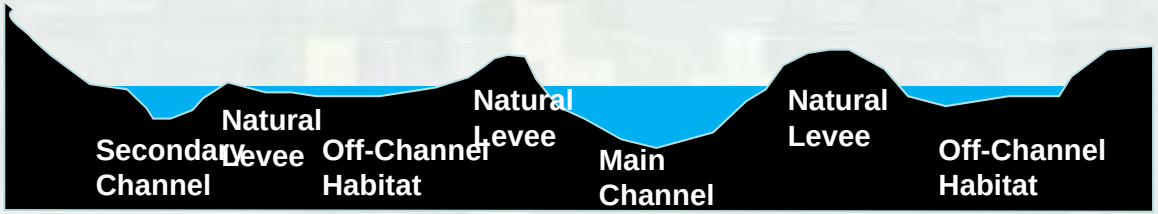
- What caused secondary channel erosion and increased HC,1980s to 1990s?
- What has caused the apparent leveling off and decrease of HC,1990s to present in some locations?
- Is HC on a decreasing trajectory?

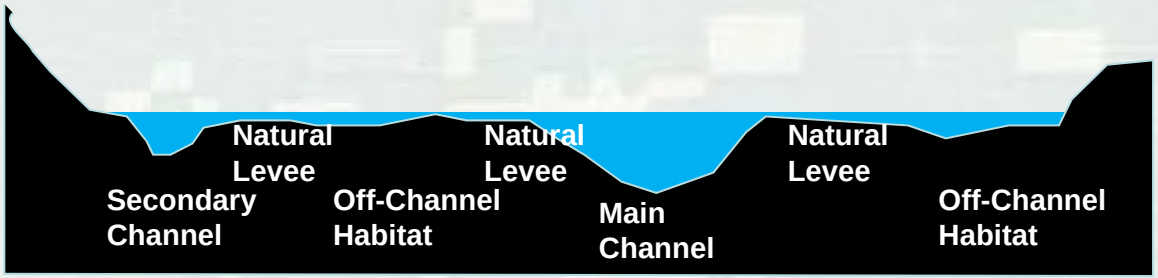




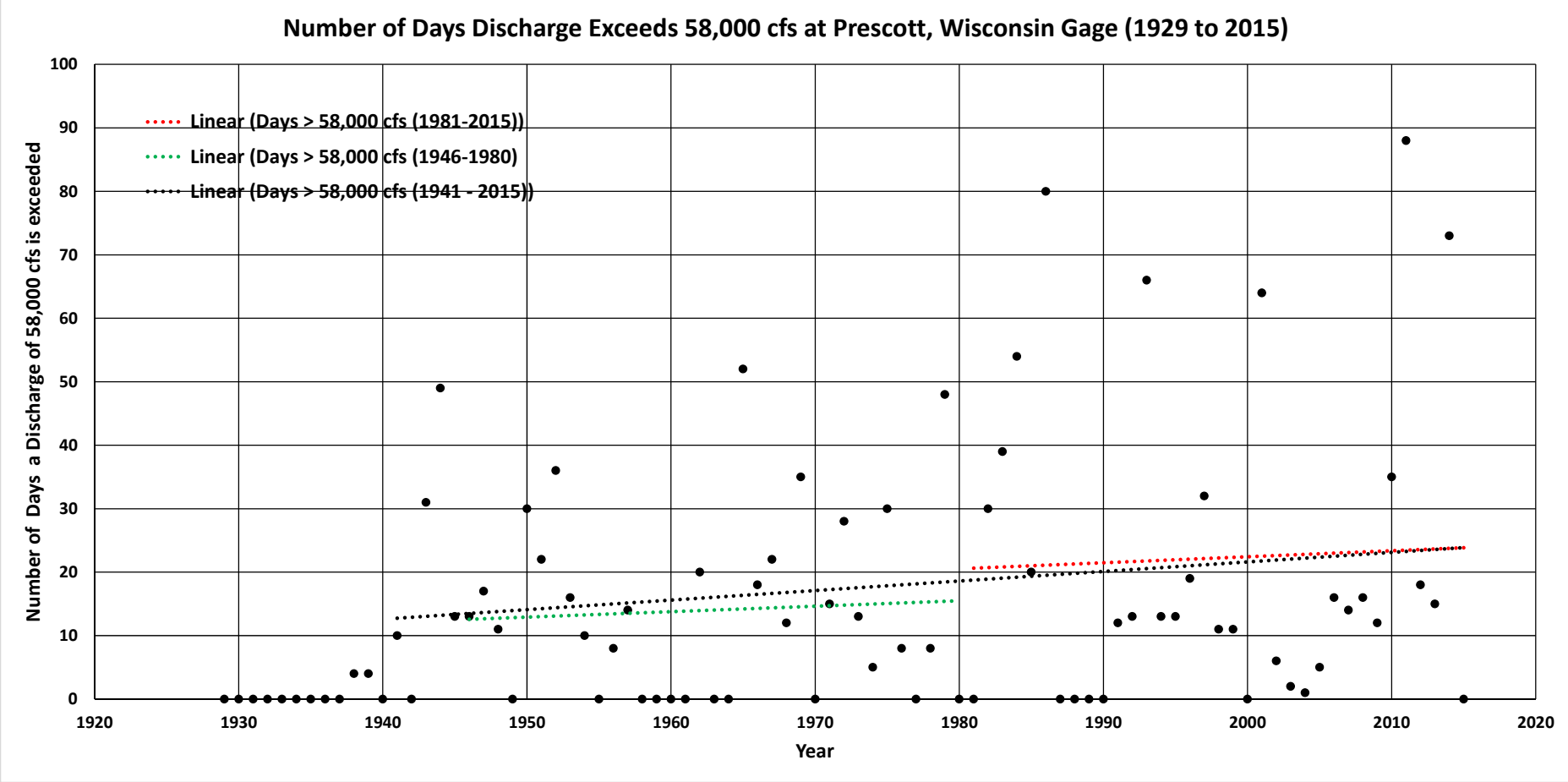
Geomorphic Response

The backwaters became a very efficient flow path resulting in secondary channel erosion

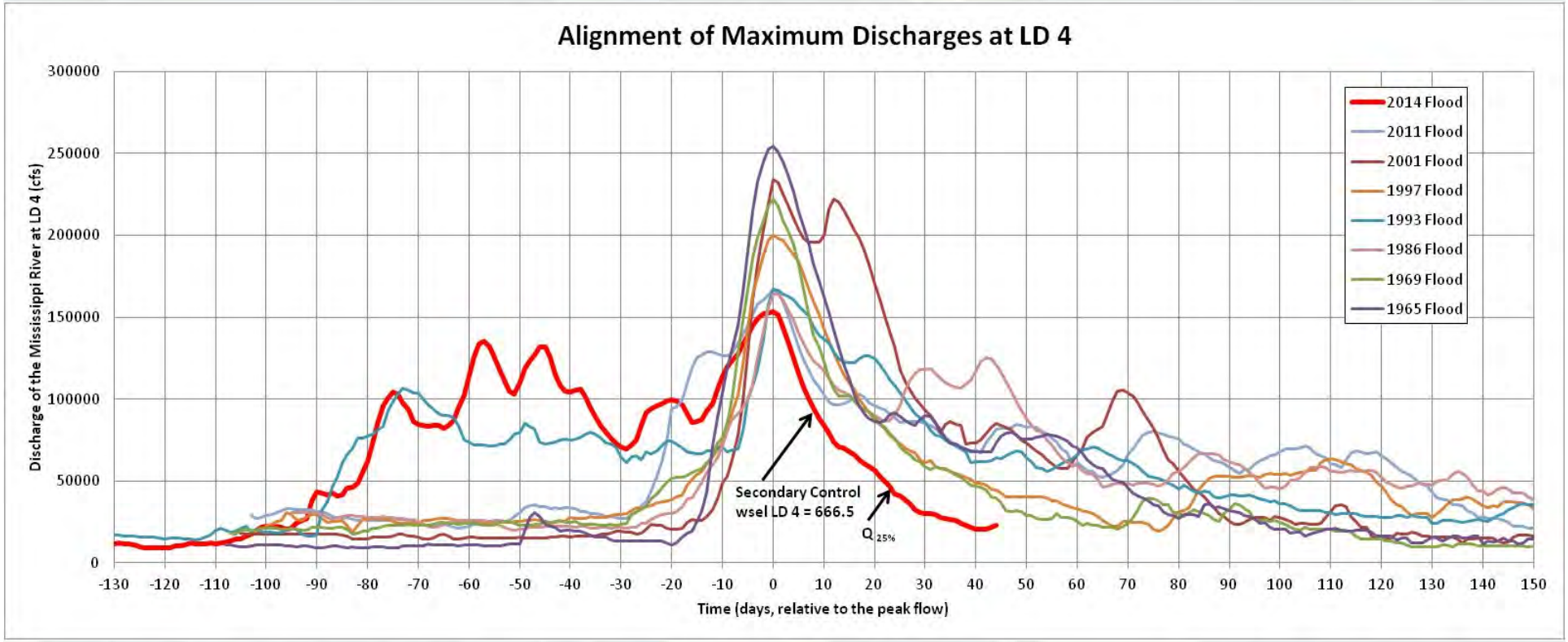


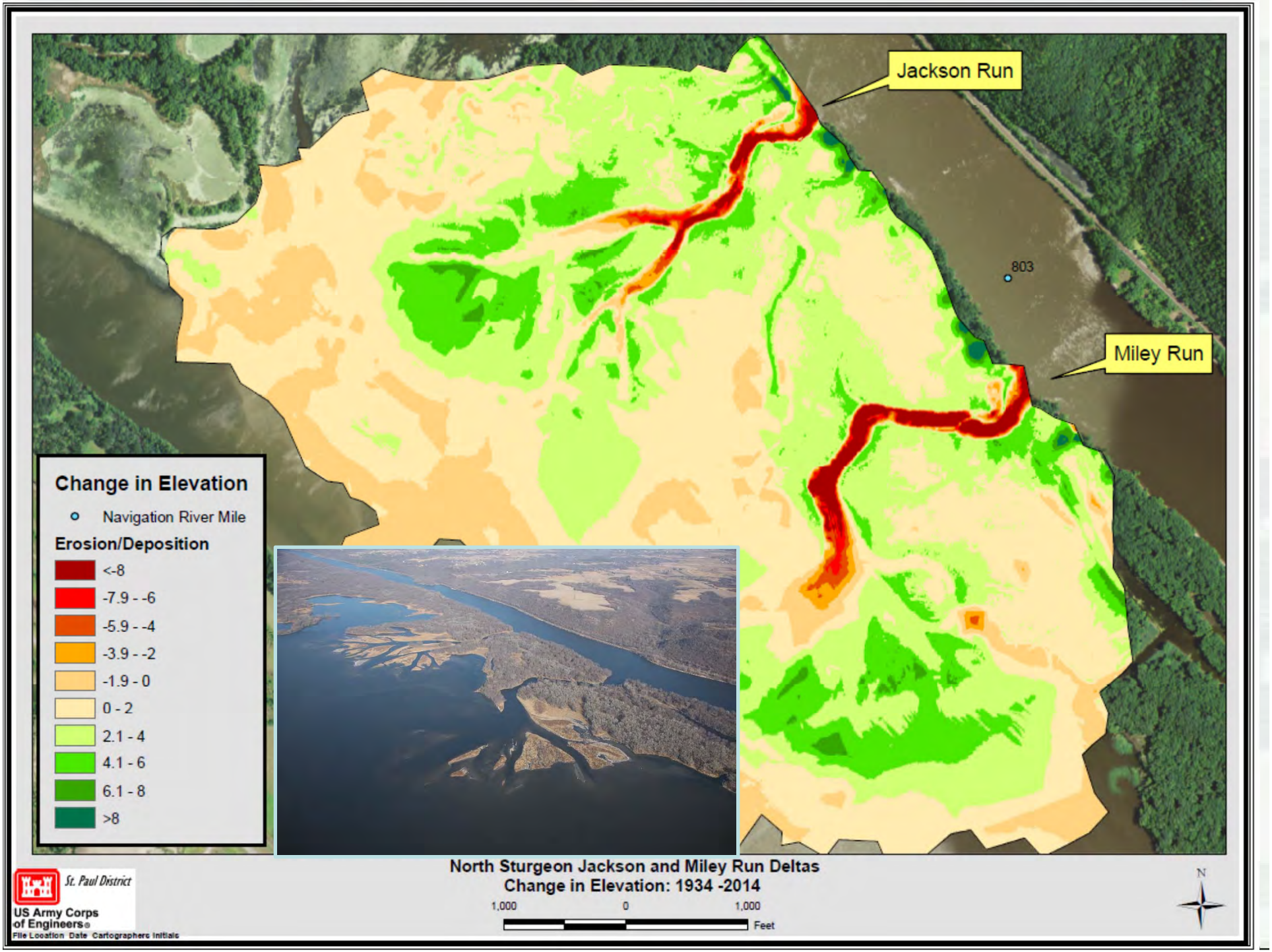


Long-term Hydrologic Effects?



Short-term Hydrologic Effects




Jackson Run
803
Miley Run
Change in Elevation
Navigation River Mile
Erosion/Deposition
<-8
-7.9 - -6
-5.9 - -4
-3.9 - -2
-1.9 - 0
0 - 2
2.1 - 4
4.1 - 6
6.1 - 8
>8
St. Paul District
US Army Corps of Engineers
File Location Date Cartographers Initials
North Sturgeon Jackson and Miley Run Deltas
Change in Elevation: 1934 -2014
1,000
0
1,000
Feet
N

The Physics of Diversions, 20 Sept 2016 Webinar

Gary Brown, Engineer Research and Development Center, USACE

- As time progresses, deposition in the diversion outfall will become emergent land and begin to obstruct flow. This will induce an increase in the water surface elevation at the downstream end, and an upstream extension of the of the zone of deposition.
- When the water surface elevation increases to the point where the diversion can no longer pass the design flow, the diversion can no longer be operated at full capacity.