Indian Slough
Pool 4 Mississippi River
Habitat Rehabilitation and Enhancement Project
Project Evaluation Report

Environmental Management Program for the Upper Mississippi River System

December 2011

Table of Contents

1 Introduction

1.1 UMRS EMP

The Upper Mississippi River System Environmental Management Program (UMRS-EMP) is a Federal-State partnership to manage, restore, and monitor the UMRS ecosystem. The UMRS-EMP was authorized by Congress in Section 1103 of the Water Resources Development Act of 1986 (Public Law 99-662) and reauthorized in 1999. Subsequent amendments have helped shape the two major components of EMP – the Habitat Rehabilitation and Enhancement Projects (HREPs) and the Long Term Resource Monitoring Program (LTRMP) (USACE 2010). Together, HREPs and LTRMP are designed to improve the environmental health of the UMRS and increase our understanding of its natural resources (USACE 2010).

The EMP was the first program in the Nation to combine ecosystem restoration with scientific monitoring and research efforts on a large river system (USACE 2010). The EMP has served the Nation well for 25 years on the UMRS, completing 56 habitat projects benefiting approximately 100,000 acres of aquatic and floodplain habitat and contributing significantly to our scientific understanding of this complex system through monitoring and research (USACE 2010). As of October 2011, nine additional projects were under active construction and another 25 were in various planning and design stages. These projects range in size from small bank stabilization efforts that might cost less than a million dollars, to larger island or water level management projects that may exceed 15 million dollars. Most projects consist of several different restoration actions.

In addition to its achievements on the UMRS, the EMP has served as a model for other aquatic ecosystem efforts both nationally and internationally (USACE 2010). The program has matured and adapted to changing conditions and new scientific insights and continues to be an efficient and effective means of ensuring that the UMRS remains both a nationally significant ecosystem and nationally significant navigation system (USACE 2010).

1.2 Habitat Rehabilitation and Enhancement Projects

Habitat Rehabilitation and Enhancement Project (HREP) construction is one element of the UMRS-EMP. The projects provide site-specific ecosystem restoration, and are intended and designed to counteract the adverse ecological effects of impoundment and river regulation through a variety of modifications, including flow introductions, modification of channel training structures, dredging, island construction, and water level management. Interagency, multi-discipline teams including personnel from the Minnesota Department of Natural Resources (MDNR), the Wisconsin Department of Natural Resources (WDNR), the United States Fish and Wildlife Service (USFWS), and the United States Army Corps of Engineers (USACE) worked together to plan and design these projects, which are located on the navigable portion of the Upper Mississippi River and its navigable tributaries.

1.3 Purpose of Habitat Project Evaluation Reports

The purposes of this habitat project evaluation report for the Indian Slough HREP are to:

- Document the pre and post-construction monitoring activities for the project.
- Evaluate project performance on the basis of project objectives and goals.
- Evaluate the project relative to other issues such as operation and maintenance.

- Make recommendations concerning future project performance evaluation.
- Make recommendations concerning the planning and design of future HREP projects.

This report summarizes available monitoring data, operation and maintenance information, and project observations made by USACE, MNDNR, WIDNR, the USFWS. It also includes other agency and public input.

1.4 Project Team

Project team members for this evaluation report included representatives from USACE, USFWS, WIDNR, and MNDNR, and are listed below. Some of these team members were also involved in the planning and construction phases of the Indian Slough project.

Much of the information in this report has been gathered from the project team members and others familiar with the project. This was accomplished through meetings and subsequent review and revisions of this report by the project team.

* Dan Wilcox	USACE	* Gary Wege	USFWS
* Dennis Anderson	USACE	Mary Stefanski	USFWS
* Don Powell	USACE	Sharonne Baylor	USFWS
Derek Ingvalson	USACE	Pam Thiel	USFWS
Jon Hendrickson	USACE	Phil Delphey	USFWS
Randy Urich	USACE	Ron Benjamin	WIDNR
Megan Kranz-McGuire	USACE	Jeff Janvrin	WIDNR
Aaron McFarlane	USACE	Brian Brecka	WIDNR
* Bob Drieslein	USFWS	Scot Johnson	MNDNR
Kevin Stauffer	MNDNR		

*Retired

1.5 Project Documents

Much of the information presented here is summarized from the Indian Slough Definite Project Report and Environmental Assessment (DPR/EA; USACE1990) and the Indian Slough Operation and Maintenance Manual (O&M Manual; USACE 1994). These reports are available from the St. Paul District on request.

2 Project Area

2.1 Location

Indian Slough and Big Lake are in lower pool 4 between river miles (R.M.) 760 and 757 on the Upper Mississippi River (Figure 1). The study area encompasses the backwater areas on the left descending (eastern) side of the main navigation channel. The project area is part of the Upper Mississippi River National Wildlife and Fish Refuge, managed by the USFWS. Portions of the project area, and the majority of Big Lake, are within Big Lake Closed Area. It is located in northern Buffalo County, Wisconsin, between the villages of Nelson and Alma, Wisconsin. The closest city is Wabasha, Minnesota across the river to the southwest.

Figure 1. Indian Slough project area map.

2.2 Project Area

The general project area is bounded on the northwest by Highway 25, which crosses the Mississippi River from Nelson, Wisconsin, to Wabasha, Minnesota; on the northeast by the Burlington Northern – Santa Fe Railroad which runs along the Wisconsin shore of the river; and on south by the main channel of the Mississippi River.

The project area is in the delta of the Chippewa River. Indian Slough is a distributary secondary channel that conveys flow from the main channel into Big Lake, a backwater area in lower Pool 4. The project area includes Indian Slough, Crats Island, Big Lake Bay, and the upper part of Big Lake. A good portion of the area to the north and the east of Indian Slough lie within the Big Lake Closed Area. This area has been designated as being closed to migratory bird hunting since 2009.

The project area boundaries in Figure 1 were not shown in the DPR/EA (USACE 1994). The boundaries were delineated for use in the HREP database in 2010. The project area shown in Figure 1 covers 827 acres.

2.3 **Pre-project Habitat Conditions and Historic Changes**

Hydraulic alteration and sedimentation were identified in the DPR/EA as the primary processes affecting habitat conditions in the project area. The 1932 Brown Survey, corrected for post-inundation conditions (1940); the 1974 U.S. Geological Survey 7.5-minute topographic quadrangle map, and U. S. Fish and Wildlife Service1984 aerial photographs (scale 1:24,000) were digitized and plan form changes were analyzed with GIS. Three areas were found to have changed significantly in land/water area.

The main channel border of the Mississippi River increased in land area due to channel maintenance dredged material placement and accretion of sediment. The historical channel maintenance activities near the mouth of Indian Slough were estimated to have contributed greatly to the sedimentation in Indian Slough and Big Lake. The placement of the dredged material in areas adjacent to the main channel and the Crats Island placement site left sparsely vegetated sand with limited wildlife habitat value.

Another area of major change was downstream of the Highway 25 causeway and bridges. There was a substantial increase in land area along and downstream of the existing channels. Highway 25 modifications done in the 1950's included the placement of bridges in new areas. Instead of dredging channels to accommodate the changed flow conditions, new channels formed under the bridges. The substantial changes in land and water areas downstream of Highway 25 may be at least partially explained by the erosion and deposition that occurred as a result of the highway upgrade.

Since inundation by the 9-Foot Channel Navigation Project, the extent of natural rock substrate has become limited to the rock channel training structures that were built as part of the 41/2 - and 6 - foot navigation projects. These structures are important because they provide good habitat for a variety of lithophilic (preferring rock substrate) fish species. Dredged material deposits and sediment accumulation covered much of the channel training structures.

A third area that has shown dramatic changes in land/water area is adjacent to Indian Slough, including the upper end of Big Lake. There, approximately 240 acres of aquatic area present in 1940 changed to land. Although no bathymetric surveys are available, it appears that much of upper Big Lake became shallower through sediment deposition.

Truedale Lake declined from 160 acres of open water in 1940 to about 80 acres in 1984. An island had also formed across the mouth of Truedale Lake, effectively isolating it from Truedale Slough. Truedale Lake is now an isolated shallow wetland very productive for a variety of aquatic life forms, but its value as year-round fish habitat declined.

Big Lake Bay followed a similar trend as the Indian Slough delta encroached on this area. The increased flows through Indian Slough and its meandering channel configuration caused bank erosion along the channel, further adding to sedimentation in Big Lake. From 1940 to 1984, Indian Slough, from its original inlet at the main channel border to immediately downstream of where Truedale Slough branches from Indian Slough, increased in surface area by 40 percent. One area where this erosion was substantial is just downstream from where Truedale Slough branches from Indian Slough.

In addition to the gradual changes in Indian Slough channel habitat, the increased area of the sand delta at the mouth of Indian Slough significantly modified water circulation patterns within Big Lake. Previously, water from Indian Slough flowed through several small channels within the delta area, providing flow to various portions of Big Lake including Big Lake Bay. In 1990 most of the flow was concentrated in only one channel which flows in an east/northeasterly direction in the delta, restricting water exchange in the upper part of Big Lake, especially in Big Lake Bay.

Sediment also restricted flow in portions of Whorehouse Slough, Truedale Slough, and Pontoon Slough, and tertiary channels that convey water from the Chippewa River delta under Wisconsin Highway 25 bridges into Indian Slough.

According to resource managers in 1990, Big Lake Bay was experiencing occasional low winter D.O. (dissolved oxygen) conditions and excessively warm summer temperatures. Efforts to monitor pre-project winter water quality conditions did not find low winter D.O. concentrations due to consecutive mild winters with limited snow cover.

2.4 **Pre-Project Habitat Types and Distribution**

The general project area covered approximately 3,500 acres of floodplain habitat. Figure 2 shows 1989 land cover based on LTRMP interpreted aerial photography.

The bottomland forest which covered about 1,000 acres was dominated by American elm (*Ulmus americana*), silver maple (*Acer saccharinum*), cottonwood (*Populus deltoides*) , black willow (*Salix* nigra) and river birch (*Betula nigra*). Scattered stands of dense sandbar willows (*Salix interior*), near the water's edge, occurred throughout the study area. The understory was dominated by poison ivy (*Rhus radicans*) and wood nettle (*Laportea canadensis*).

According to Meyers (1976), in 1973 emergent and marsh vegetation covered about 1,000 acres of the general study area. Extensive, dense stands of arrowheads (*Sagittaria* spp.) and river bulrush (*Scirpus fluviatilis*) occurred throughout the study area. Cattails (*Typha latifolia*), softstem bulrush (*Scirpus validus*), and burreed (*Sparganium eurycarpum*) occurred in scattered stands throughout the study area. Lotus (*Nelumbo lutea*) occurred in beds in the deeper areas of the Big Lake area.

Open water, consisting of river lakes, ponds, and channels covered 1,500 acres of the general study area. In the shallower water zones interspersed in these open water areas, were submersed and emergent aquatic plants. The abundant submersed vegetation included extensive beds of pondweeds (*Potamogeton crispus*, P. *zosteriformus*, P. *foliosus*, and P. americanus, *Stuckenia pectinatus*), coontail (*Ceratophyllum demersum*), wild celery (*Vallisneria americana*), water star grass (*Heteranthra dubia*), and waterweed (*Elodea canadensis*) . Water lily (*Nymphaea* spp.) was frequently found along with some of the submerged species.

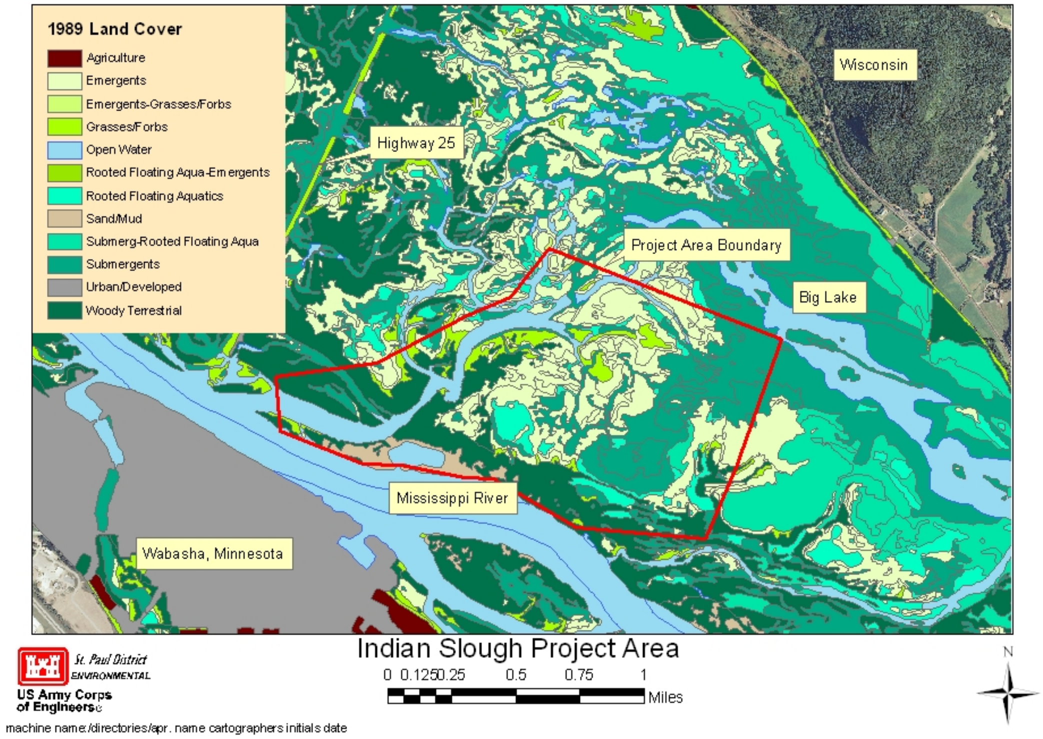

Figure 2. 1989 land cover in the Indian Slough HREP area.

2.5 Fish and Wildlife in the Project Area

The Indian Slough/Big Lake complex contains a diversity of aquatic habitat types and supports a variety of fish species. Big Lake and the smaller ponds, lakes, and tertiary channels in the area support an excellent sport fishery, including bluegill (*Lepomis macrochirus*), black crappie (*Promoxis nigromaculatus*), largemouth bass (*Micropterus salmoides*), and northern pike (*Esox lucius*).

Indian Slough, Catfish Slough, the main channel and other larger channels in the project area support Centrarchids and riverine species, such as walleye (*Sander vitreum*) and smallmouth bass (*Micropterus dolomieui*).

The diversity and quality of habitat types in the project area make it a productive area for a variety of wildlife species. The Indian Slough delta area in Big Lake has an abundance of sand islands containing herbaceous vegetation, lying only 1 to 3 feet above normal pool level which provides excellent shorebird habitat. Truedale Lake and the western and southern margins of Big Lake, which contain large areas of marsh, shallow water, and deepwater wetlands provide valuable habitat for puddle ducks. Mammals, such as the muskrat (*Ondatra zibethicus*), are also abundant in these marsh areas. During migrations, diving ducks occur in great numbers in the more open water areas of Big Lake containing submersed vegetation.

Tundra swans (*Cignus columbianus*) use the lower Pool 4 area during fall migration, especially the marsh area in Big Lake and Reicks Lake at the mouth of the Buffalo River, which is located immediately downstream of the project area.

Although the project area was still very productive for fish and wildlife, there were certain problem areas. Habitat conditions in the upper end of Big Lake were changing rapidly, mainly as a result of the sediment load from Indian Slough. Aquatic areas in the Indian Slough delta were becoming shallower and changing to land. In addition, over time, the formation of the Indian Slough delta had modified water circulation patterns, causing dissolved oxygen problems in Big Lake Bay. This had diminished the value of the 75-acre bay as winter habitat for lentic fishes.

2.6 Threatened and Endangered Species in the Project Area

When the DPR/EA was prepared, there were three federally-listed endangered (E) and threatened (T) species known to occur in the project area; Peregrine falcon (E) Bald eagle (T), and Higgins' eye pearly mussel (E).

The bald eagle was delisted on August 8, 2007 and the peregrine falcon was delisted on October 5, 1994. There have been no adverse effects of the project on these species.

Although Higgin's eye pearly mussels presently occur in Pools 3 and 5, none have been recently reported from lower Pool 4.

3 Project Goals and Objectives

3.1 General Goals

The primary purpose of the project was to reduce the continuing loss and degradation of aquatic habitat within Big Lake and adjacent channels, resulting from the sediment load through Indian Slough (USACE 1990).

3.2 Specific Project Objectives

Project objectives stated in the DPR (USACE 1990) are:

1. Reduce the conversion of Big Lake Bay and Indian Slough's shallow and deepwater wetlands to land by at least 50%
2. Maintain dissolved oxygen levels of at least 5 mg/l throughout most of winter and hot summer periods in at least 15% of Big Lake Bay
3. Reestablish 10 acres of flowing slough habitat
4. Enhance 11 acres of Indian Slough for lithophilic fish species
5. Restore/maintain Big Lake Bay as centrarchid fish habitat

4 Project Description

The Indian Slough project was designed to reduce water and sediment flow through Indian Slough, restore fish habitat in Indian Slough, and to restore water depths and water quality conditions for fish winter habitat in Big Lake Bay.

4.1 Project Features

Partial Closing Structure on Indian Slough

A partial closing structure was designed to reduce water and sediment flow into Indian Slough and Big Lake. The partial closure structure is two L-shaped rock embankments, one extending from each bank (Figure 3). The short legs across the Indian Slough channel were constructed on top of an old wing dam. The top of this structure is at elevation 671 ft (all elevations are in feet, 1912 adjustment mean sea level datum), tying into the existing banks. The top of the closing structure is 10 feet wide. Side slopes are 1 ft vertical: 3 ft horizontal.

In the DPR/EA (USACE 1990), the design called for the downstream – oriented legs to form a 300-ft-long triangular notched structure with a water surface top width of 65 ft and a depth of 13 ft at normal pool elevation of 667 ft (Figure 4).

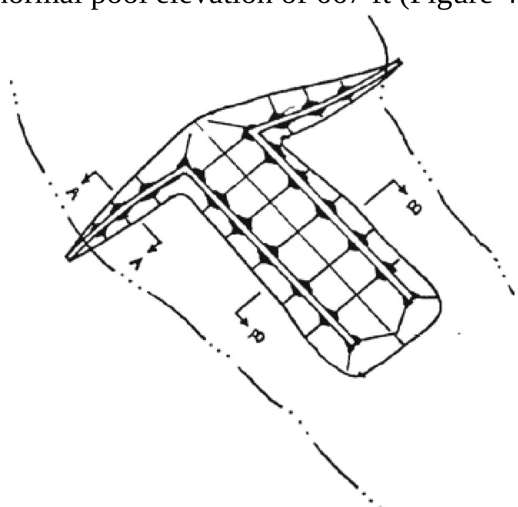

Figure 3. Plan view of Indian Slough closing structure original design. Flow is from to top to bottom (from DPR/EA).

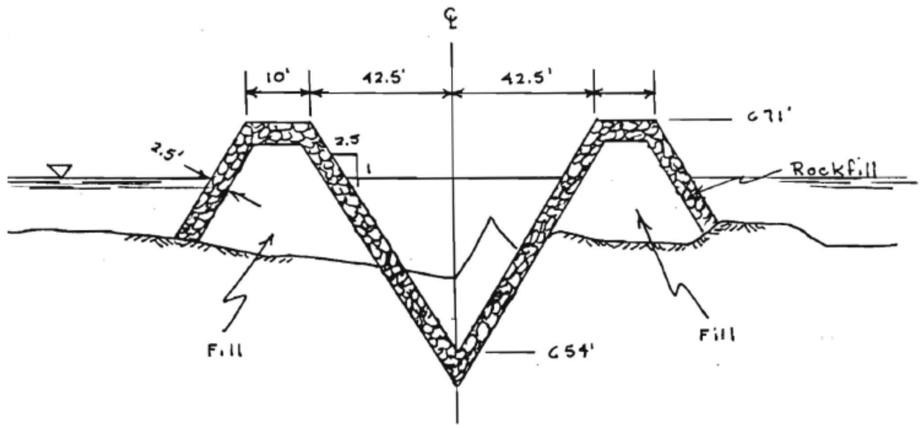

Figure 4. Cross section of Indian Slough closing structure (from DPR/EA).

The opening through the closure structure was designed to reduce sediment loading into Indian Slough and Big Lake while allowing at least a minimum flow into the backwater area.

The closing structure was constructed in a different orientation than described in the DPR/EA with the long legs facing upstream (Figure 5). This was done to further reduce water and sediment flow through the structure over the original design. The closing structure constructed is based on a re-entrant culvert design that results in eddies on either side of the entrance. These eddies effectively reduce the cross sectional area of the structure at its entrance. This allows the channel to be constructed a little wider to facilitate recreational boat traffic, while still reducing flow and sediment.

The closing structure was designed to pass a minimum flow of 375 cfs (cubic feet per second) to provide adequate circulation and D.O. in the backwaters.

Fill material for the closing structure was obtained from Whorehouse Slough, restoring that to a flowing channel (Figure 6). A small shallow-draft hydraulic dredge was used to deepen Whorehouse Slough.

Figure 5. Indian Slough closing structure. River flow is from left to right. Whorehouse Slough at upper right (2009 Google Earth imagery).

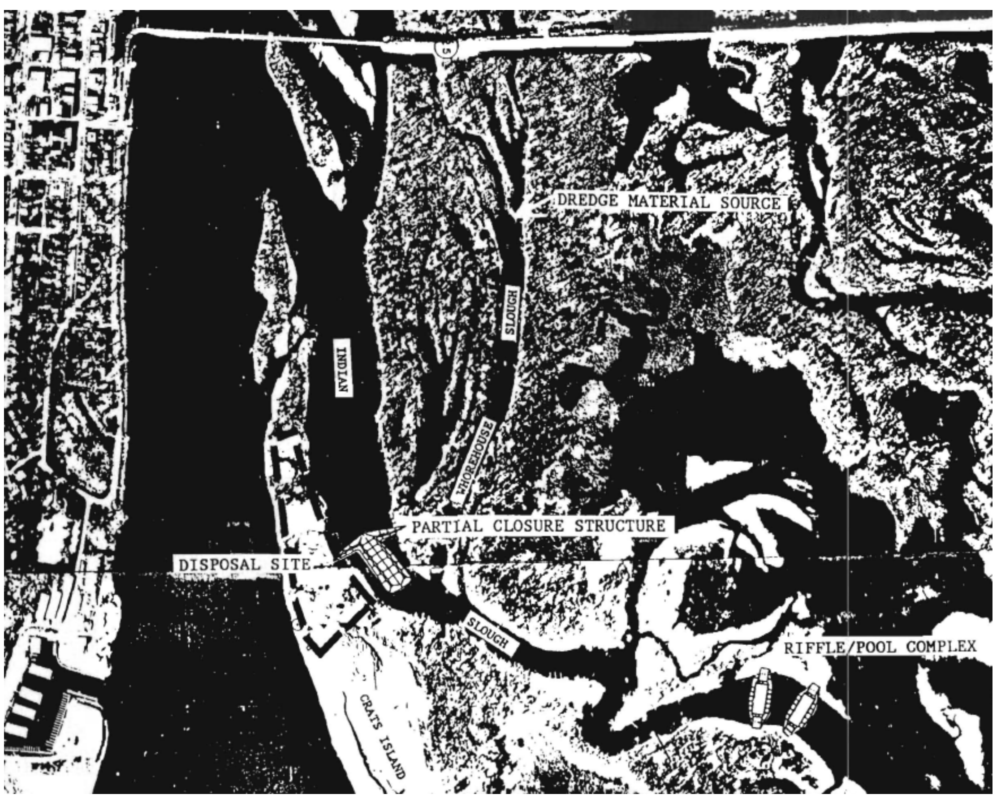

Figure 6. Closing structure in Indian Slough, dredging area in Whorehouse Slough for closing structure, riffle – pool complex in Indian Slough and disposal site on Crats Island for material dredged from Big Lake Bay (from DPR/EA).

Figure 7. Aerial view of Indian Slough looking northeast. Partial closing structure at lower left, ends of riffle structures along channel in middle right. Crats Island dredged material placement site at bottom center. Planted areas are at upstream and downstream ends of the Crats Island Dredged Material Placement site. WIDNR photo. September 2006.

Rock Shoreline Stabilization Features

A low spot in the left bank of Indian Slough upstream of the closing structure was reinforced with approximately 500 cubic yards (cy) of fill and 250 cy of rock riprap to stabilize this area and prevent breakout of flow into Whorehouse Slough.

To minimize the amount of additional water and sediment that would flow into Robinson Lake (across the main channel and downstream of Indian Slough) due to construction of the closing structure on Indian Slough, two channels leading into Robinson Lake were stabilized with approximately 600 cy of rock.

Another channel potentially affected by construction of the partial closing structure on Indian Slough is Catfish Slough, an additional secondary channel flowing into Big Lake. Approximately 200 cy of rock riprap was placed to stabilize the banks of Catfish Slough at its divergence from the main channel (Figure 11).

Channel Habitat Restoration in Indian Slough

Habitat restoration in Indian Slough was designed to provide habitat for fish like smallmouth bass that occupy channels with rock and wood substrate.

Rock Riffles and Pools

The restoration of channel habitat included the construction of a riffle-pool complex in Indian Slough. The riffle-pool complex consists of two rock riffle areas alternating with two 200-foot long pool areas (Figures 7 and 8). The rock riffles were designed with a minimum rock thickness of 30 inches. The top elevation of the rock riffles was established to provide a minimum of 4 feet of water and to provide clearance for recreational boat traffic. The pool areas downstream of the riffle structures were dredged to a depth of 8 feet to maximize habitat benefits while limiting the cost of dredging.

Wood and Log Crib Installations

A series of whole trees with root wads attached (Figures 7 and 8) were placed along 400 feet of eroded bank upstream of the riffle-pool complex to provide wood habitat structure for fish and macroinvertebrates. Fifteen log crib structures (Figure 9) were placed in the pools to also provide woody habitat structure for fish and macroinvertebrates.

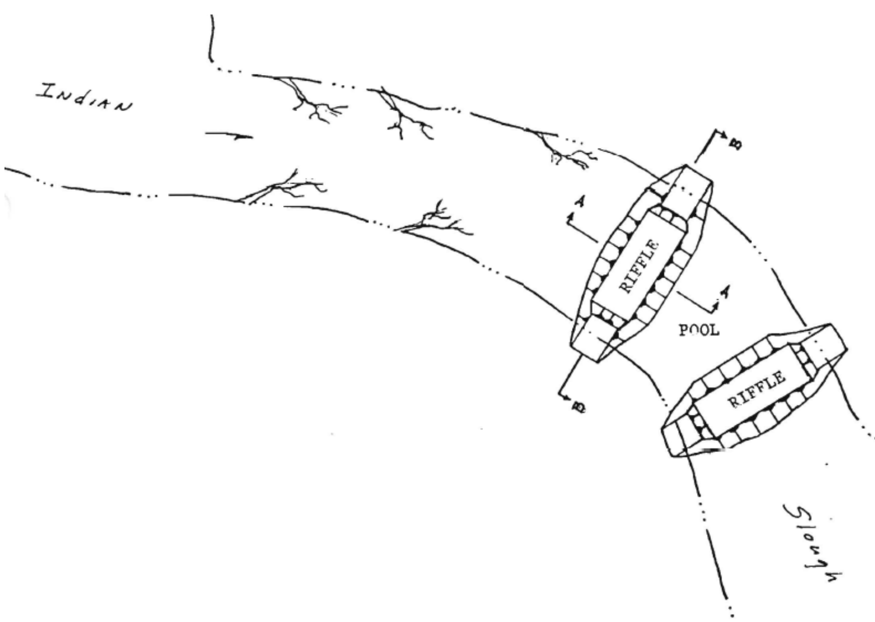

Figure 8. Layout of the rock riffles and pool complex in Indian Slough, with trees anchored to the banks upstream.

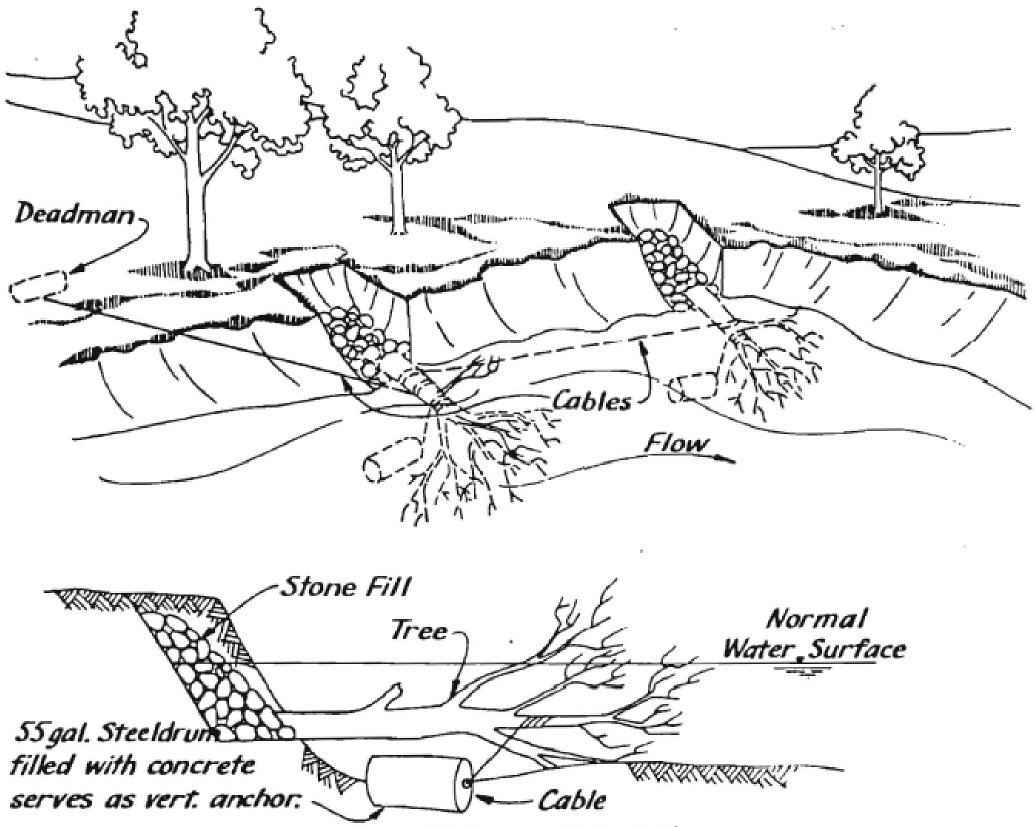

Figure 9. Design of the tree installations along the banks of Indian Slough upstream of the riffle-pool complex.

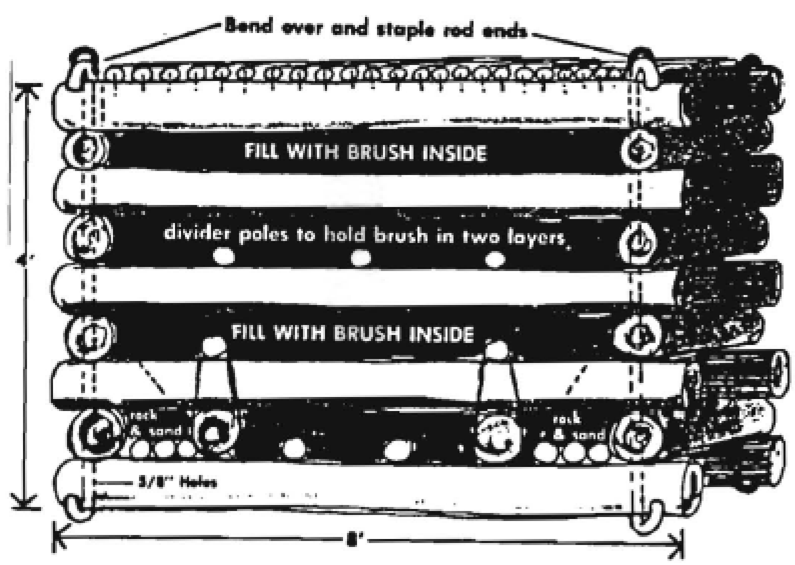

Figure 10. Design of the log and brush cribs installed in the pools of the riffle-pool complex in Indian Slough.

<u>Dredging in Big Lake Bay</u>

Dredging in Big Lake was done to increase water depths in a shallow area that historically provided good winter habitat for fish. Approximately 46,000 cy of fine material dredged from Big Lake Bay was used to cap 10 acres of dredged material in the Crats Island placement site. The area and depth of dredging in Big Lake Bay were sized to match the available placement site capacity and to tie the dredged area into the deeper portions of Big Lake. The restoration of water depths consisted of deepening approximately 11 acres of Big Lake by about 2.5 feet. The dredged channel in Big Lake Bay (Figure 11) was approximately 3,000 feet long with a bottom width of 125 feet and depth of 5 feet.

The two areas where the fine-grained dredged material was placed on Crats Island were seeded in May 1994 (Anfang 1995). Burr oak tree seedlings were also planted on the site. The areas were drill seeded with the following mixture and mulched:

big bluestem (Andropogon gerardi) 3 lb/ac
little bluestem (Andropogon scoparius) 3 lb/ac
Indian grass (Sorghastrum nutans) 3 lb/ac
switchgrass (Panicum virga tum) 3 lb/ac
side oats grams (Bouteloua curtipendula) 1 lb/ac
prairie dropseed (Sporobolus heterolepsis) 2 lb/ac
perennial rye (Lolium perenne) 20 lb bulk/ac

A minimum of four of the forbs listed below were also seeded:

black-eyed Susan (Rudbeckia hirta) 4 oz/ac
yellow coneflower (Ratiblda columnifers) 1 oz/ac
rough blazing star (Liatris aspera) 2 oz/ac
prairie clovers (Petalostemun sp.) 3 oz/ac
leadplant (Amorpha canescens) 2 oz/ac
stiff tickseed (Coreopsis palmata) 3 oz/ac

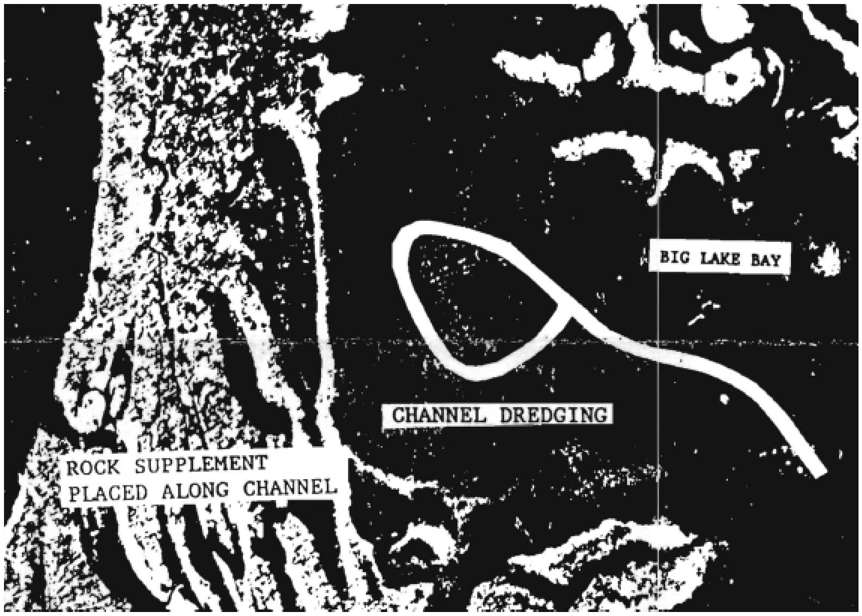

Figure 11. Channel dredged in Big Lake Bay. "Rock supplement placed along channel" refers to rock placed to stabilize the entrance to Catfish Slough (from DPR/EA).

4.2 Planning and Implementation History

Planning for the Indian Slough Project began in 1989. The draft DPR/EA was completed in June of 1990 and the report was approved for implementation by the North Central Division of USACE in 1991.

Construction began in 1992. The USACE Rivers and Harbors unit did the Stage 1 construction work, completing the riffle-pool complex in November 1992 and the partial closing structure in November 1993. This work cost $722,000 and was done with Navigation Project operation and maintenance funds.

Stage 2 of the project construction was the dredging in Big Lake Bay. The dredging and material placement was completed in June 1993 by J.F. Brennan Company, Inc. at a cost of $266,000.

The contractor spread the fine material from Big Lake Bay on approximately 10 acres of old dredged material on the north and south sides of the Crats Island placement site. The Corps Natural Resources Section planted native prairie grass and forb seed to vegetate the north site. Corps staff planted 1,975 seedling trees, forbs and prairie grass on the south site with USFWS assistance with the intent to create a savanna community. Tree shelters and weed protection mats were placed on about 25 percent of the trees.

The Operation and Maintenance Manual (USACE 1994) was completed in October 1994. A monitoring report on revegetation of the fine material from the Big Lake Bay dredging placed on Crats Island (Anfang and Wege 1997) was prepared in October 1997. A sounding survey of Indian Slough was done in November 2004. A vegetation survey and assessment of the Crats Island planted areas was conducted in 2011(Appendix A).

4.3 Construction Cost

The cost for Stage 1 construction by the Corps was $722,000, funded through the Corps operation and maintenance budget for the 9-Foot Channel Navigation Project. Contract dredging of Big Lake Bay Stage 2 work was $266,000, funded through the EMP. Tree and native prairie vegetation planting by the Corps cost approximately $6,000, also funded through the EMP. Total project construction cost was $994,000.

5 Operation and Maintenance

5.1 Operation and Maintenance Responsibilities

The USFWS has responsibility for the maintenance of the Indian Slough project. A Memorandum of Agreement for the Indian Slough project was signed by the Corps and the USFWS dated September 17, 1992 (Appendix B in USACE 1994).

Improvements or alterations to the project would be coordinated with the partner agencies.

The USFWS was to submit an annual report to the St. Paul District Engineer. The Corps and the USFWS were to conduct a joint inspection of the project once every five years, with invitation to the WIDNR to participate. These plans for inspections and reporting were developed during preparation of plans and specifications for the project and were to be modified by mutual agreement.

The St. Paul District has responsibility for monitoring condition of the partial closing structure and downstream hydraulic effects on flow through Indian Slough, the main channel, Catfish Slough and channels leading into Robinson Lake.

5.2 Operation and Maintenance Tasks and Schedule

The Operation and Maintenance Manual calls for annual visual inspection of the riffle-pool structure, as well as soundings once every three years for the riffle-pool structure and the Big Lake Bay dredge cuts. The inspections are subject to change by mutual agreement between the Corps and the USFWS.

There are no project features that require operation.

5.3 History of Major Disturbances

Since the Indian Slough project was completed in 1994, there have been 11 major floods with discharge > 100,000 cfs at Lock and Dam 4 (Figure 11). During that time, the largest flood was in 2001. Long duration floods occurred in 2002 and 2010.

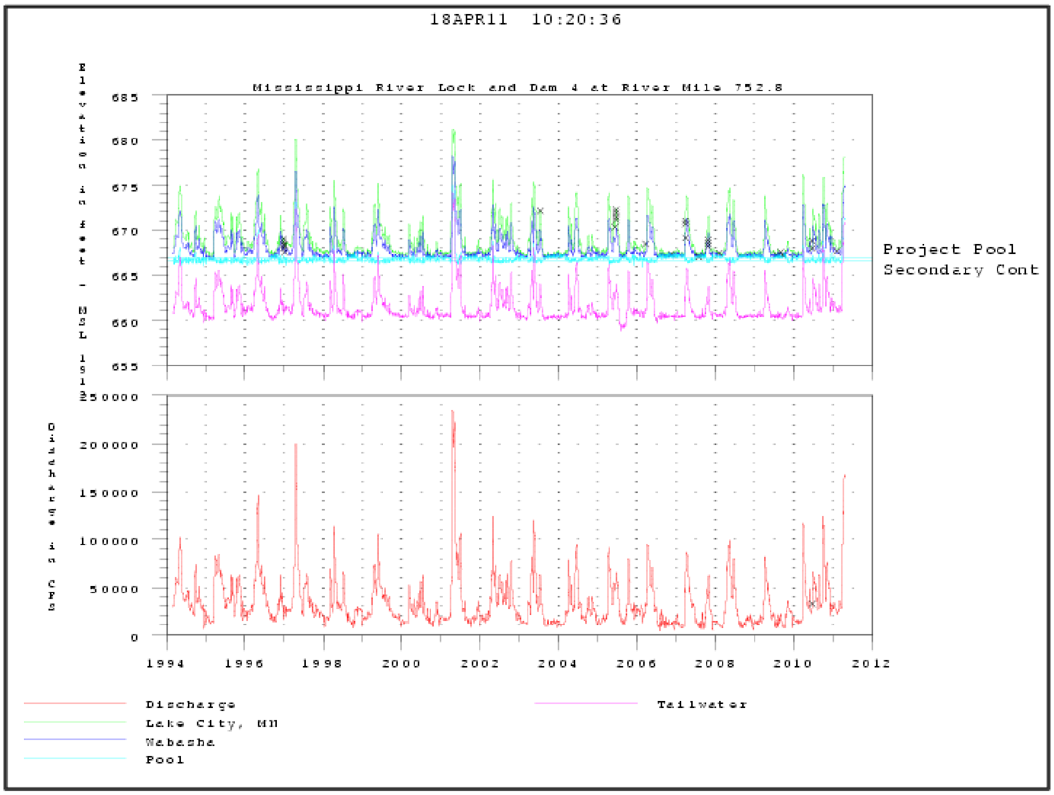

Figure 11. Stage and discharge hydrograph at Lock and Dam 4, Mississippi River, 1994 – 2011.

According to the National Weather Service, Pepin and Buffalo Counties had 9 and 8 hurricane force (>75 mph) wind events, respectively, during 1970 – 2010. Not all these wind events affected the project area, but there were a number of strong wind events associated with thunderstorms that felled many of the shallow-rooted trees in the floodplain.

5.4 Operation and Maintenance Cost and History

Records of maintenance activities and costs prior to 1997 were not available, but it appears that no actions were taken. No maintenance activities have been conducted from 2007 to the present. Table 1 is the list of historic maintenance activities and costs. The estimated costs are from the project DPR (USACE 1990).

USACE-MVP-0000120538

Table 1. History of maintenance activities and costs.

Year	Years in O&M	Estimated Annual Cost w/ Inflation	Actual FWS Costs	Activities
1994	1	$567	$0	
1995	2	$583	$0	
1996	3	$600	$0	
1997	4	$614	$1,375	Crats Island prescribed burn. Cut Chinese elm and treated stumps.
1998	5	$624	$620	Crats Island prescribed burn. Periodic inspection.
1999	6	$637	$0	
2000	7	$659	$0	
2001	8	$677	$0	
2002	9	$688	$0	
FY2003	10	$704	$0	
FY2004	12	$719	$0	
FY2006	13	$762	$384	Researched sediment issue. Inspected project.
FY2007	14	$784	$720	Inspected project
FY2008	15	$813	$0	
FY2009	16	$810	$0	
FY2010	17	$823	$0	

5.5 Other Events Affecting the Project Area

The Crats Island dredged material placement site was off-loaded of 1,427,000 cy of dredged material in 1987. Since then, dredged material has been added almost annually to the site, a total of 1,349,863 cy.

6 Project Monitoring

6.1 Monitoring Plan

The monitoring plan in the DPR/EA (USACE 1994) focused on the project objectives (Table 2).

Table 2. Monitoring plan summary from the DPR/EA (USACE 1990).

Objectives	Monitoring Activities
Reduce rate of conversion of aquatic habitat to land in Big Lake delta area by 50%	- Monitor land/water area with aerial photography - Monitor flow in Indian Slough, estimate reduction in 2-year recurrence interval discharge - Monitor changes in Indian Slough geometry
Maintain 5 mg/l D.O. summer and winter in at least 15% of Big Lake Bay	- Monitor D.O., water temperature and current velocity in winter - Monitor diel D.O. and water temperature in summer
Enhance habitat in 11 acres of Indian Slough for lithophilic fish species	- Monitor flow pattern through Indian Slough - Monitor geometry of Indian Slough - Monitor the wood installations and the riffle-pool complex

In addition to these monitoring activities described in the DPR/EA, an unstated project objective was to re-vegetate approximately 10 acres of the Crats Island dredged material placement site where fine material dredged from Big Lake Bay was placed. Monitoring was to include vegetation cover and species composition.

6.2 Monitoring History

Monitoring work was conducted by the Corps, the WIDNR, the MNDNR, the USGS Upper Midwest Environmental Science Center (UMESC) and the Long-Term Resource Monitoring Program (LTRMP) Pool 4 Field Station. Table 3 lists the monitoring activities that were conducted.

6.3 Pre-project Monitoring

6.3.1 Bathymetric Surveys

A bathymetric survey of Pool 4 including Indian Slough was conducted by the Corps in 1992 to establish pre-project conditions for project design (Figure 12).

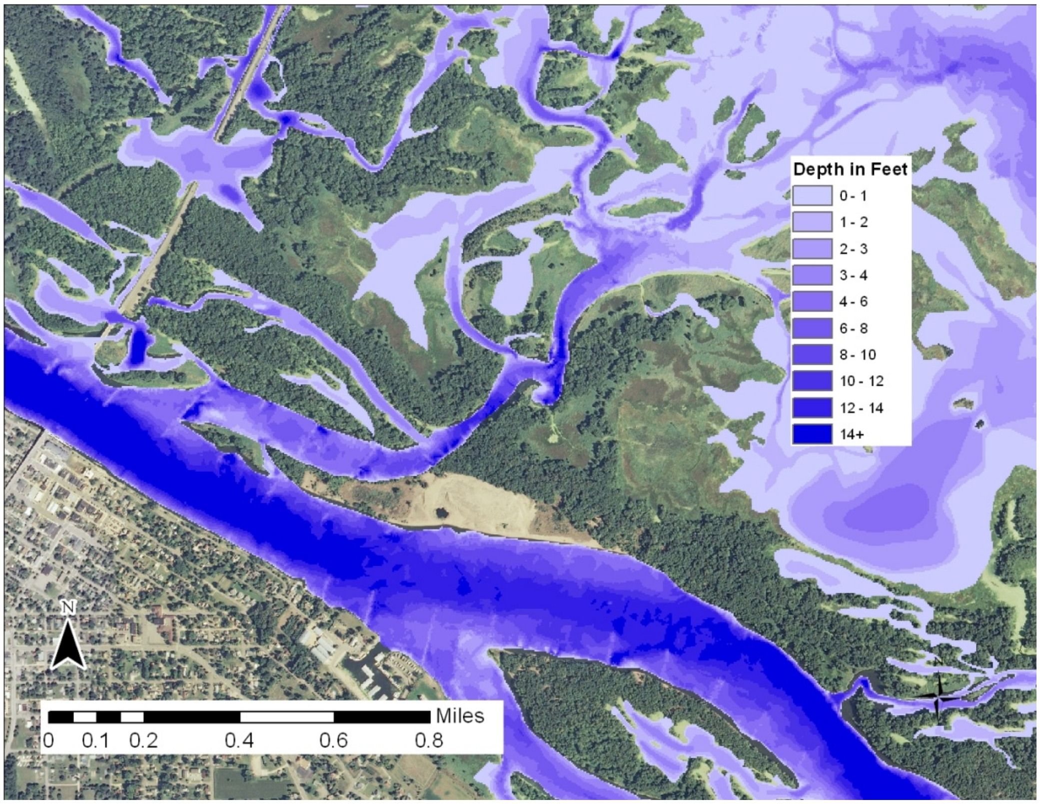

Figure 12. Bathymetry survey map of Pool 4 from 1992. Depths are in feet.

A bathymetric survey was done by the Corps in Big Lake Bay in 1992 to establish pre-project conditions and to plan for the proposed dredging (Figure 13). Although the scanned hard copy record from that survey is difficult to read at the scale printed in this report, water depths in Big Lake Bay were generally 2.5 to 3.5 ft deep.

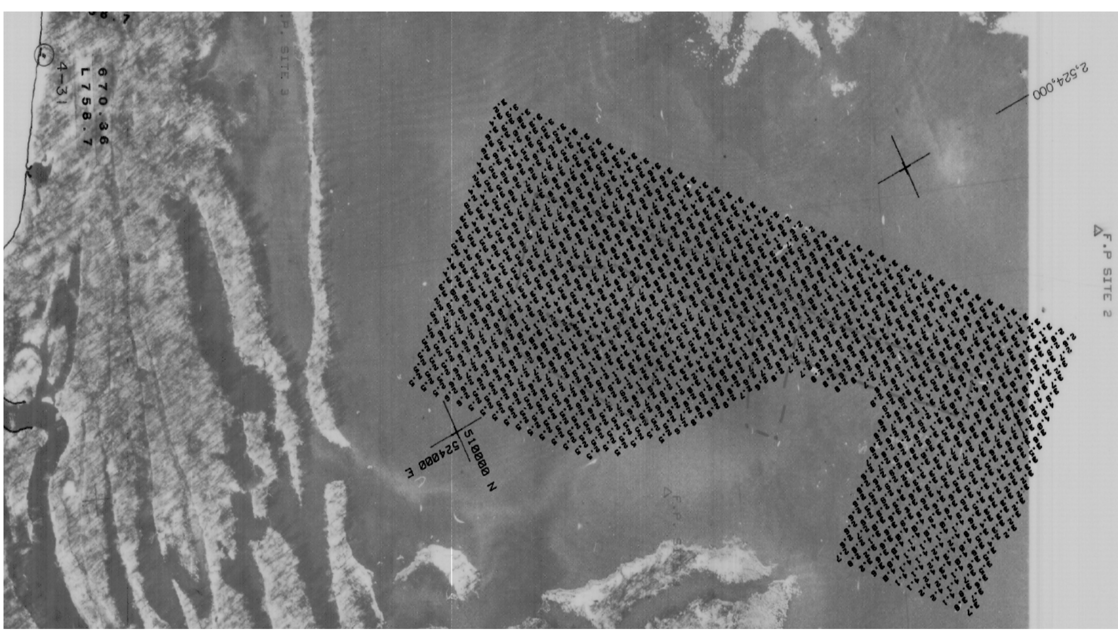

Figure 13. Bathymetric survey of Big Lake Bay 1992.

Table 3. Monitoring activities at the Indian Slough project.

Project Ecosystem Objectives

1. Reduce the conversion of Big Lake Bay and Indian Slough's shallow and deepwater wetlands to land by at least 50%
2. Maintain disolved oxygen levels of at least 5 mg/l throughout most of winter and hot summer periods in at least 15% of wetlands in Big Lake Bay
3. Reestablish 10 acres of flowing slough habitat
4. Enhance 11 acres of Indian Slough for lithophilic fish species
5. Restore/maintain Big Lake Bay as centrarchid habitat

Parameter Monitored	Unit of Measurement	Period of Record	Number of Records	Agency	Results	Relation to Project Objective	File Name
Electrofishing, fyke nets	CPUE, size, PSD	Aug 1987 - April 1988	3	WI DNR	relatively stable populations	Fish Habitat (4,5)	Indian_PreProject_Fishery_Inventory_I_88.pdf
Electrofishing, fyke nets	CPUE, size, PSD	Aug 1987 - April 1995	12	WI DNR		Fish Habitat (4,5)	Indian_Fish_Sampling_I_95.pdf
Pool 4 Discharges	m3/sec	7/12/89 - 10/24/96	12 Indian Slough	USACE		May be relevant to (1,3)	Pool4_Discharge_Measurements_I_P_96.pdf
DO	mg/L	12/21/90 - 3/8/91	4 Primary; 14 one-time	MDNR	All >7.8mg/l	Pre-Project monitoring (2,5)	Big_Lake_Bay_Preproject_I_91.pdf
Water Temperature	°C	12/21/90 - 3/8/91	4 Primary; 14 one-time	MDNR	-0.02°C - 3.8°C	Pre-Project monitoring (2,5)	Big_Lake_Bay_Preproject_I_91.pdf
Current Velocity	m/s	12/21/90 - 3/8/91	4 Primary; 14 one-time	MDNR	0-.04	Pre-Project monitoring (2)	Big_Lake_Bay_Preproject_I_91.pdf
DO	mg/L	Jan 5 - Feb 22 1994	74	LTRMP	All surface and bottom >5	Maintain DO levels (2,5)	Big_Lake_Bay_Post_Monitoring_I_94.pdf
Water Temperature	°C	Jan 5 - Feb 22 1994	74	LTRMP	Surface 0°-1.2° Bottom 0°-2.5°	Centrarchid Habitat (5)	Big_Lake_Bay_Post_Monitoring_I_94.pdf
Water Depth	cm	Jan 5 - Feb 22 1994	37	LTRMP	range of 47cm-184cm	Centrarchid Habitat (5)	Big_Lake_Bay_Post_Monitoring_I_94.pdf
Ice thickness	cm	Jan 5 - Feb 22 1994	37	LTRMP	increased (34-36)-(47-59)		Big_Lake_Bay_Post_Monitoring_I_94.pdf
Snow Depth	cm	Jan 5 - Feb 22 1994	37	LTRMP			Big_Lake_Bay_Post_Monitoring_I_94.pdf
Current Velocity	m/s	Feb 22 1994	32	LTRMP	.01-.04m/s	Centrarchid Habitat (5)	Big_Lake_Bay_Post_Monitoring_I_94.pdf
Soil Analysis for Fines	% passing sieve	1994	1	USACE			Indian_Reveg_Monitoring_I_95.pdf
Robel Reading		1995	1	USACE	1.9 - target was 1.5		Indian_Reveg_Monitoring_I_95.pdf
Vegetation Frequency		1995	1	USACE			Indian_Reveg_Monitoring_I_95.pdf
Vegetation Dominance		1995	1	USACE			Indian_Reveg_Monitoring_I_95.pdf
Vegetation Importance		1995	1	USACE			Indian_Reveg_Monitoring_I_95.pdf
Vegetation Spp. List		1995	1	USACE			Indian_Reveg_Monitoring_I_95.pdf
Increase in Discharge	%	7/12/89 - 10/24/96	2	USACE	Comparison of Indian,Catfish,Robinson,Truedale		Discharge_Graphs_I.pdf
Increase in Discharge	cfs	7/12/89 - 10/24/96	2	USACE	Comparison of Indian,Catfish,Robinson,Truedale		Discharge_Graphs_I.pdf

6.3.2 Hydraulic Measurements

Current velocity and channel cross section measurements were made by the Corps in Indian Slough, Catfish Slough, the main channel, and in channels leading into Robinson Lake in 1989-1992 to allow discharge calculations and to evaluate the hydraulic effects of the proposed project.

6.3.3 Summer Water Quality in Big Lake Bay

The WIDNR found that summer D.O. and water temperature in Big Lake had diel (day to night) fluctuations similar to other backwater areas in the Upper Mississippi River (Schellhaass and Sullivan 1988).

The USFWS Environmental Management Technical Center (EMTC; Belanger et al. 1990) sampled D.O. and water temperature in Big Lake Bay in August 1990. Diel changes in D.O. and water temperature were measured with a continuous monitoring device. D.O. ranged from as low as 2.99 mg/l at night to a daytime high of 11.70 mg/l. Early morning D.O. concentrations were around 5 mg/l in most of Big Lake Bay during two days in August. Lower concentrations occurred near the bottom and in the north end of Big Lake Bay. Results indicated that D.O. concentrations in Big Lake Bay during the hot part of the summer may be stressful to fish because of wide diurnal D.O. changes with concentrations falling to below 5 mg/l at night.

6.3.4 Winter Water Quality in Big Lake Bay

The WIDNR monitored Big Lake for current velocity and direction, water temperature and D.O. on three dates between January 12 and February 15, 1989 (Bartsch and Sullivan 1989). The winter of 1988-1989 was mild with sporadic snowfall. The duration of the snow cover on the ice was generally short. Dissolved oxygen measurements in Big Lake were all above 5 mg/l, ranging from 17.0 mg/l on January 25 to 6.9 mg/l on January 12. D.O. concentrations indicated that photosynthetic activity may provide an important source of D.O. during winter in Big Lake. D.O. depletion was not found at the stations (2D, 2E and 2F) that were located in Big Lake Bay. Current velocities at the stations in Big Lake Bay ranged from undetectable to 0.6 cm/sec.

Winter monitoring of water temperature, D.O. and current velocity was conducted in Big Lake Bay during December 31, 1990 through March 8, 1991 by the EMTC (Dieterman, 1991). December was mild that winter, but ice formed by the end of the month and the rest of the winter was typical. Monitoring was done at 18 locations on 5 transects. Biweekly monitoring of D.O. and water temperature was conducted at four primary sites during the period of ice cover on six dates. All fourteen additional sites were sampled once on February 8, 1991 during a period of stable river flow and pool elevation for D.O. and water temperature, along with current velocity and direction. The lowest D.O. concentration measured that winter in Big Lake Bay was 7.8 mg/l. D.O. was supersaturated from mid-February until ice-out. Water temperature ranged from -0.02°C to 2.9°C. Current velocity was undetectable at most locations; the highest reading was 0.04 m/s.

Evidence of oxygen depletion in Big Lake Bay was not found during the winter of 1990-91. A trace amount of flow from Indian Slough throughout Big Lake Bay may have provided oxygenated water to the area. Primary production could also have contributed significantly to maintaining oxygen levels above 7 mg/l, especially throughout February when snow cover had diminished. Noticeable algal blooms were not observed. Big Lake Bay supported a winter fishery for larger northern pike and largemouth bass, but few anglers caught panfish. This may have been due to sparse submersed aquatic vegetation in Big Lake Bay that winter.

6.3.5 **Aquatic Vegetation**

Color infra-red aerial photographs from 1975, 1989, 1991-1994 and 1996 were interpreted and digitized by UMESC to examine changes in aquatic vegetation in Big Lake (Dieck and Tyser 1999). Successional changes (from submersed vegetation to emergent and from emergent to terrestrial) were not observed. In Big Lake, open water increased from 211 ha in 1975 to 286 ha in 1996. There was no apparent effect of the HREP project on vegetation in Big Lake.

6.3.6 **Fishery Surveys**

The USFWS Upper Mississippi River National Wildlife and Fish Refuge (1980) surveyed fish in the project area in the late 1970s and recommended reducing flow into Indian Slough to reduce sedimentation in Big Lake. The WIDNR surveyed the fish community in 1979 (Talbot 1981). The sport fishery was assessed with a creel census and mark-recapture tagging study in 1983 (Benjamin and Talbot 1984).

The WIDNR (Lucchesi and Benjamin 1988) conducted electrofishing and fyke netting in August and October 1987 and in April 1988 to survey the fish community in Indian Slough and Big Lake. They reported a diverse lotic fish community of 37 species, similar to that described by Talbot (1981). Walleye, black crappie, bluegill, spotted sucker, and *Moxosoma* ssp. (redhorse) were the most abundant species sampled. Size composition indicated good reproduction and growth. Panfish were found in lotic habitats in summer and fall.

6.4 **Post-Construction Monitoring**

6.4.1 **Bathymetric Surveys – Indian Slough**

Bathymetric surveys of Indian Slough were made in 2004, 2008 and 2011. The channel response to construction of the partial closing structure and the riffle-pool complex clearly shows in the 2004 survey results (Figures 14, 15, and 16). Scour holes formed downstream of the partial closing structure and the riffles, increasing bathymetric diversity and diversity of hydraulic conditions in Indian Slough.

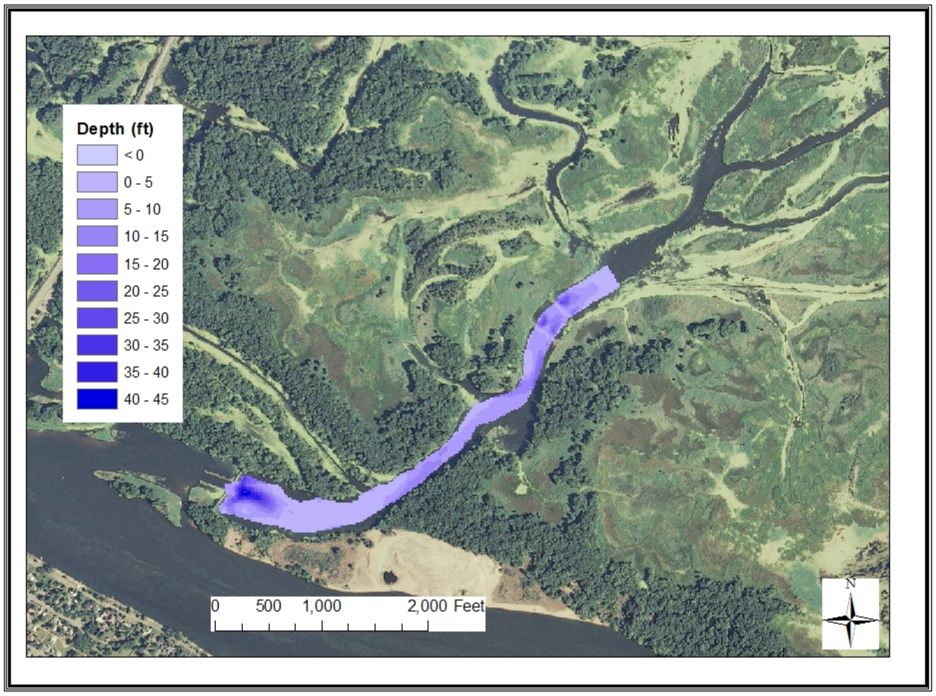

Figure 14. Bathymetric survey of Indian Slough in 2004.

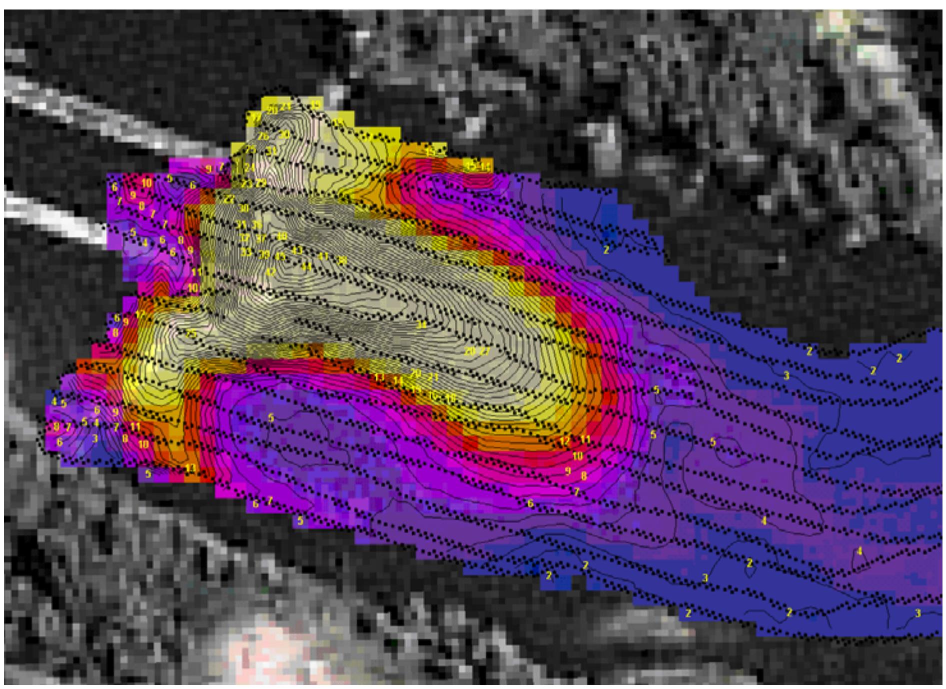

Figure 15. Scour hole below the partial closing structure. 2004 bathymetric survey. Numbers show depths in feet.

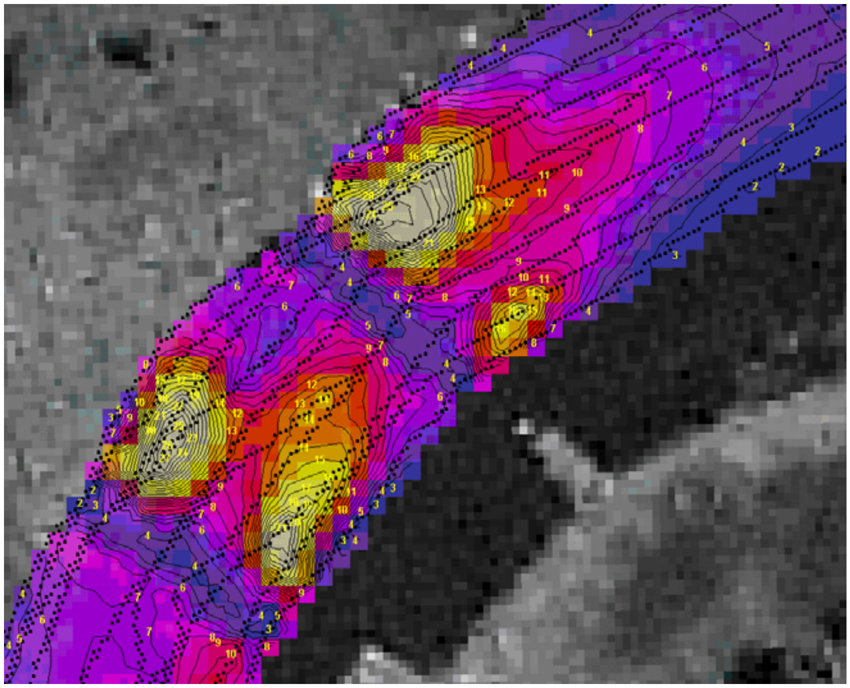

Figure 16. Riffle pool complex in Indian Slough. 2004 bathymetric survey. Numbers show depths in feet.

The 2008 bathymetric survey of Indian Slough covered more of the channel area (Figure 17).

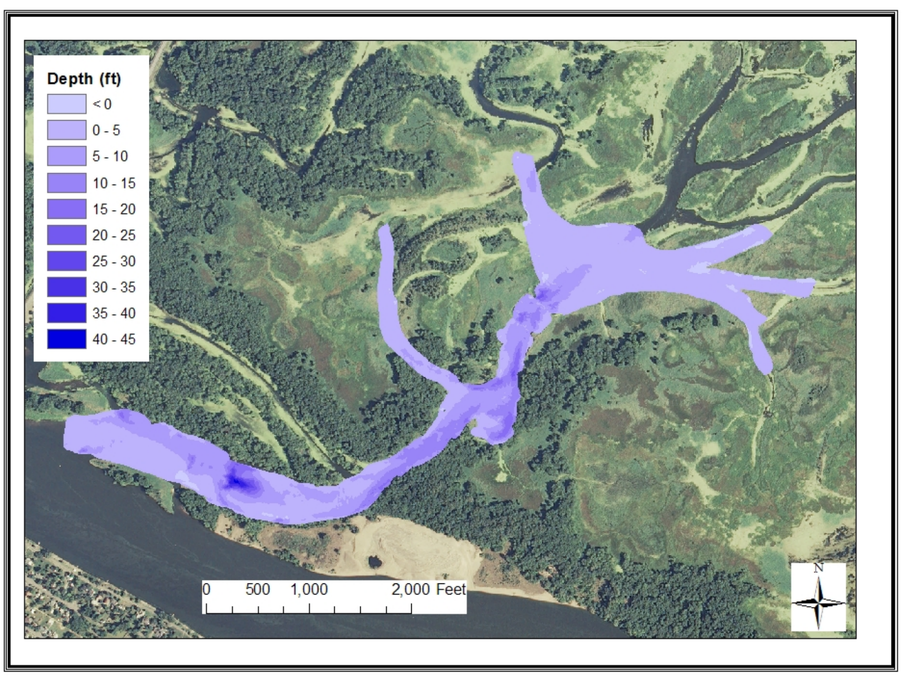

Figure 17. Bathymetric survey of Indian Slough 2008.

Another bathymetric survey of Indian Slough was conducted in June 2011 (Figure 18).

Figure 18. Bathymetric survey of Indian Slough 2011.

Changes in the geometry of Indian Slough occurred between 2004, 2008 and 2011 (Figure 19). Between the 2004 and the 2008 bathymetric surveys, much of Indian Slough became somewhat deeper and the scour holes below the closing structure and the rock riffles filled in somewhat during that time (Figure 19 top). River discharge during the 2004 -2008 period was fairly normal without major floods.

Between the 2008 and 2011 bathymetric surveys, much of Indian Slough became shallower and the scour holes became deeper (Figure 19 bottom). An extended period of high river discharge occurred in 2010 and 2011.

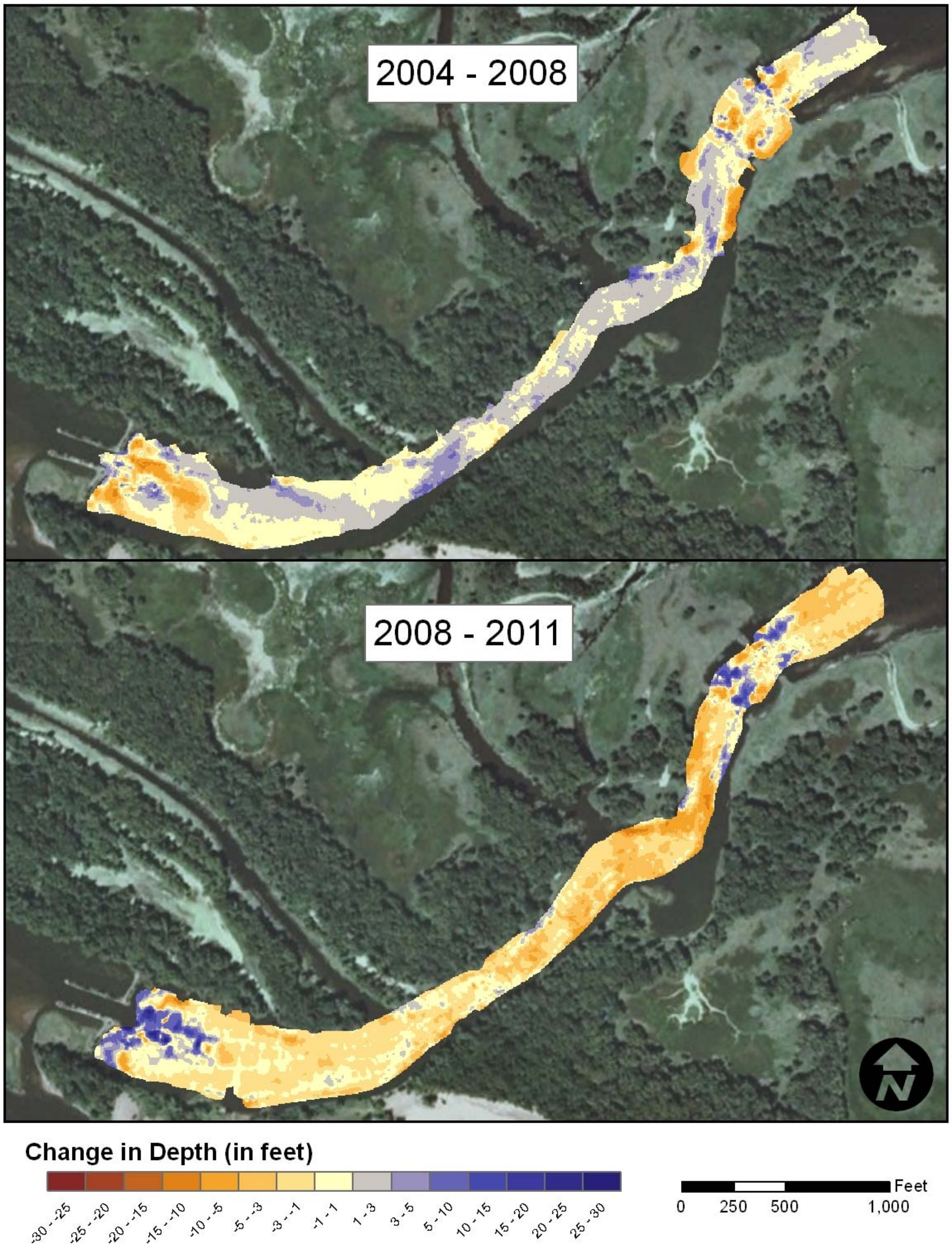

Figure 19. Changes in geometry of Indian Slough between 2004 and 2008 and between 2008 and 2011. Channel bed elevations became deeper in the blue areas and shallower in the red areas.

6.4.2 Bathymetric Surveys – Big Lake Bay

The Corps surveyed Big Lake Bay in June 1993 following excavation of the dredge cut by the contractor (Figure 21). The layout of the dredge cut was modified from that described in the DPR (Figure 10). The dredge cut was excavated to a depth of 5.0 to 5.5 ft throughout most of the cut as specified, but some of the middle part of the dredge cut was shallower at 4.4 ft deep.

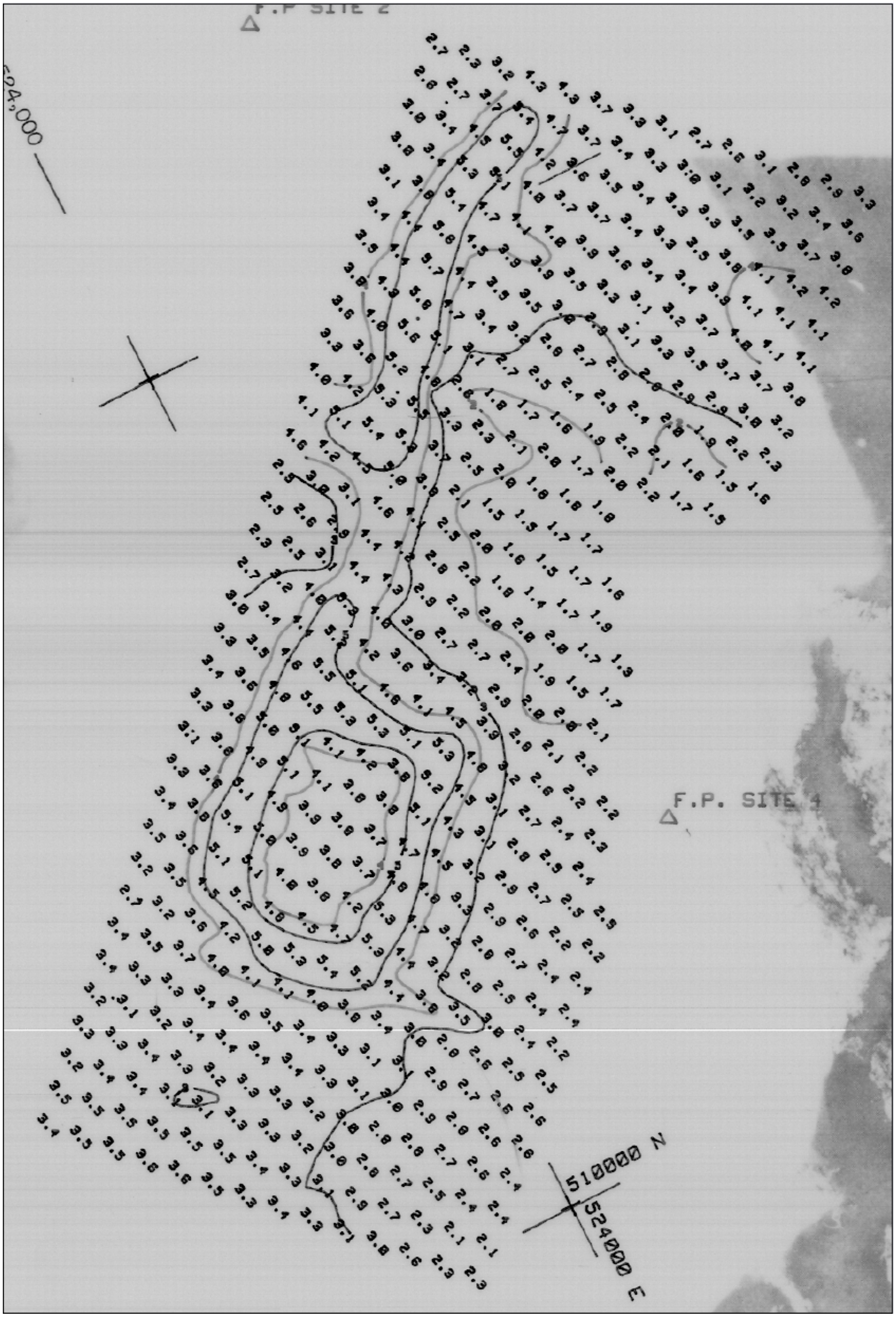

Figure 20. Bathymetric survey of the excavated channel area in Big Lake Bay June 1993.

A bathymetric survey of Big Lake Bay was conducted in June 2011 (Figure 21). Although digital data from the 1993 survey are not available, based on visual comparison of the 1993 survey map (Figure 20) and the 2011 survey map (Figure 21), it appears that the dredge cut area has filled in slightly but that the dredge cut outline remains distinct and the dredge cut area remains deeper than surrounding areas in Big Lake Bay.

There may be some discrepancy between the reference water surface elevations used in the two bathymetric surveys of the Big Lake Bay dredge cut area. The 1993 survey map was adjusted to low control pool elevation of Pool 4, but the river mile selected for the water surface elevation used for that adjustment is not known. The 2011 map was made using the estimated pool elevation at river mile 756.0 where Big Lake flows into the main channel. This should be an accurate representation of the actual water surface elevation in Big Lake Bay for adjusting to the low control pool elevation of Pool 4.

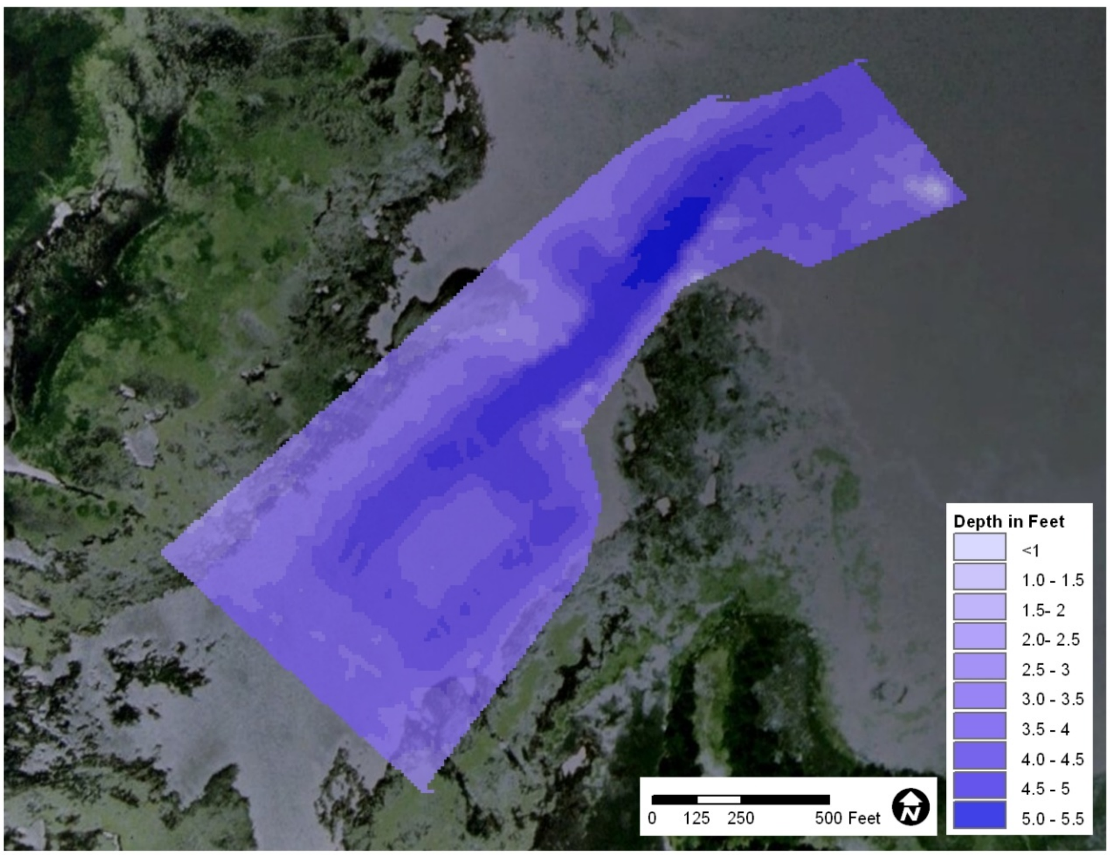

Figure 21. Bathymetric survey of Big Lake Bay conducted in June 2011.

6.4.3 Hydraulic Monitoring

Hydraulic measurements were obtained at side channels in the Indian Slough area for pre-project conditions (1989-92) and then repeated for post-project conditions (1994-1997). A limited amount of monitoring was done at several of these sites in 2002. Results indicate that the partial closing structure constructed across Indian Slough significantly reduced inflow (Figure 22). A single measurement obtained in Indian Slough in 2002, indicates that inflows continue to be reduced.

Flow into Catfish Slough did not increase significantly from the pre-project monitoring period (1989-92) to the post-project monitoring period (1994-97). However three discharge measurements obtained in 2002 indicate that flows have increased in Catfish Slough. The rock placed to stabilize the entrance of Catfish Slough did not prevent an increase in flow into Catfish Slough over time.

Similarly, flow into Robinson Lake increased following Indian Slough project construction (Figure 23). The rock placed to stabilize the entrance of Robinson Lake did not prevent an increase in flow into Robinson Lake over time.

Increased inflows into Catfish Slough and Robinson Lake may have been influenced by restricted flows into Indian Slough, resulting in slightly higher main channel water surface elevations and increased head differential between the main channel and the backwaters downstream of Indian Slough. The rock liners placed to stabilize Catfish Slough and the entrance to Robinson Lake produced scour holes in those channels, thereby increasing the cross section of those channels.

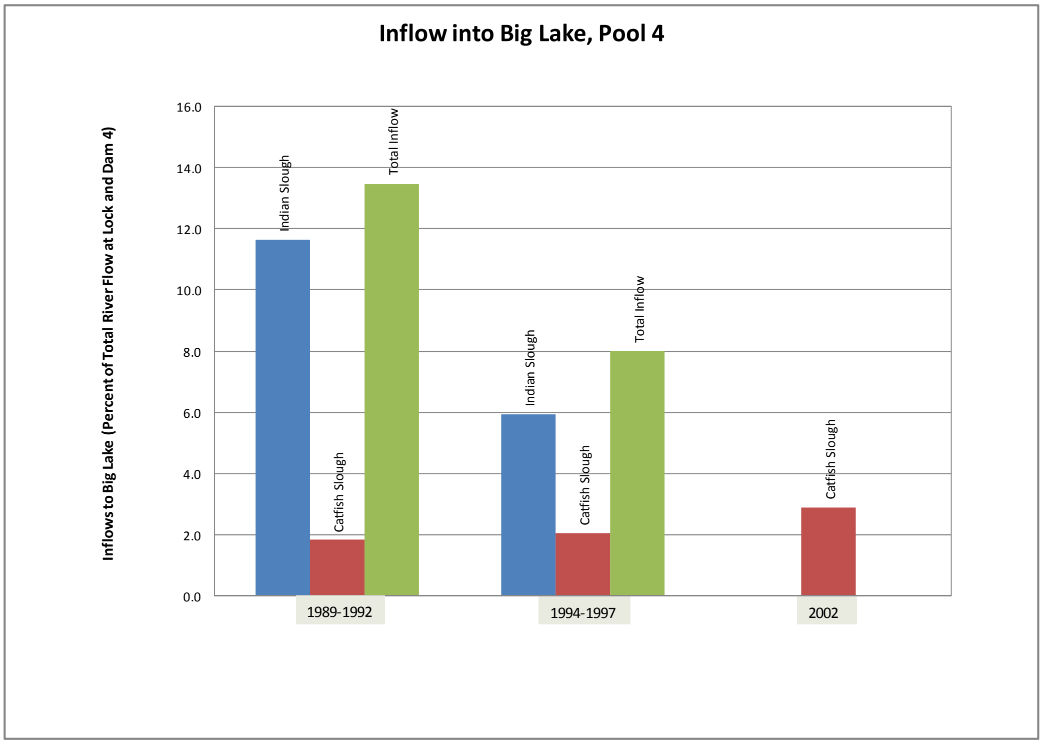

Figure 22. Results of monitoring inflows to Big Lake, Pool 4. Inflows were monitored for total river discharges varying from low flow to bankfull conditions. The results shown here are for a moderate discharge at Lock and Dam 4 (ie. the discharge exceeded 25% of the time annually). Inflows are plotted as percent of total river discharge at Lock and Dam 4.

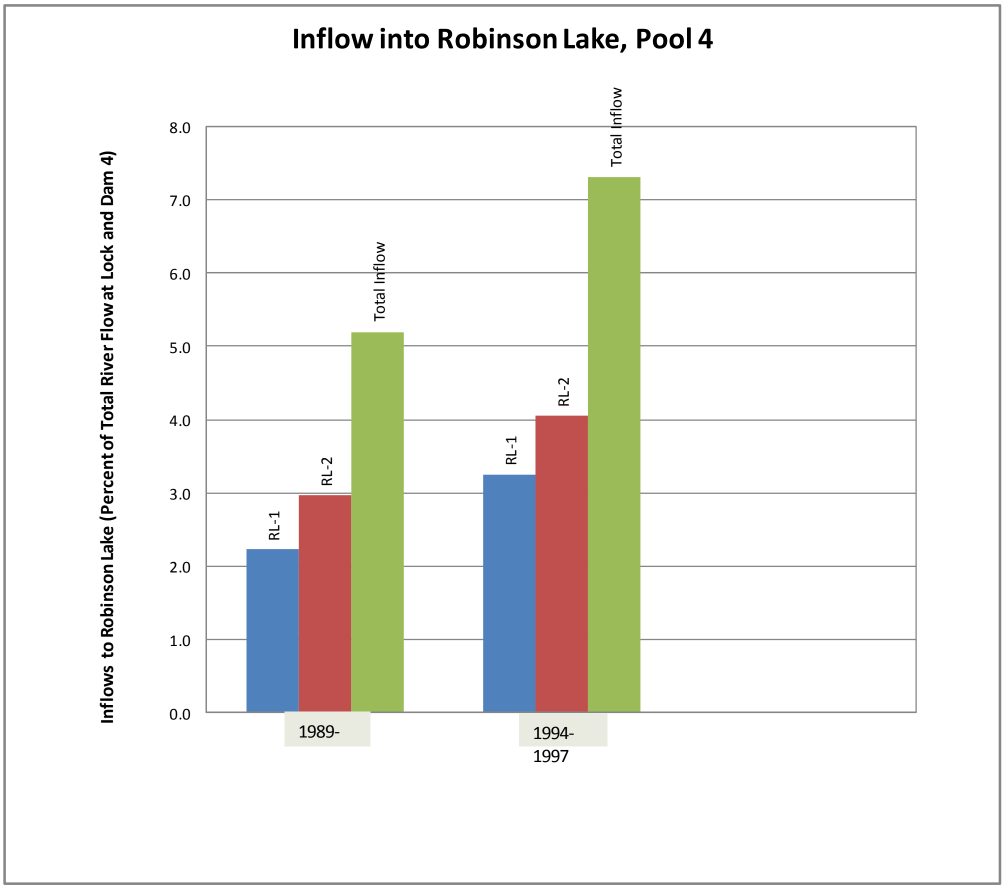

Figure 23. Results of monitoring inflows to Robinson Lake, Pool 4. Inflows were monitored for total river discharges varying from low flow to bankfull conditions. The results shown here are for a moderate discharge at Lock and Dam 4 (i.e. the discharge exceeded 25% of the time annually. Inflows are plotted as percent of total river discharge at Lock and Dam 4.

Increased lateral connectivity between the main channel and backwaters has been occurring at many locations in the upper impounded reach of the UMR (Reach Planning Team 2010). The increased flows into Catfish Slough and Robinson Lake since 1994 – 1997 probably would have occurred even if the Indian Slough partial closing structure wasn't constructed.

Hydraulic monitoring of inflows into Indian Slough, Catfish Slough and Robinson Lake continued in 2011 but were not available for this report.

6.4.4 Land Cover Monitoring

LTRMP land cover interpreted from aerial photography taken in 1989 and 2000 was used to examine land-water changes in the project area (Figure 24). Delta islands at the mouth of Indian Slough in Big Lake increased in area during the 1989 to 2000 period, and other peripheral island areas that appeared as land in 1989 changed to water by 2000. This erosion of island areas probably was due to littoral processes of wind and wave action on Big Lake coupled with reduced delta-forming sediment delivery from Indian Slough. Catfish Slough widened and some delta islands formed where that channel enters Big Lake (bottom right in Figure 24). Overall, there was not much change in land and water areas during the 1989 to 2000 period.

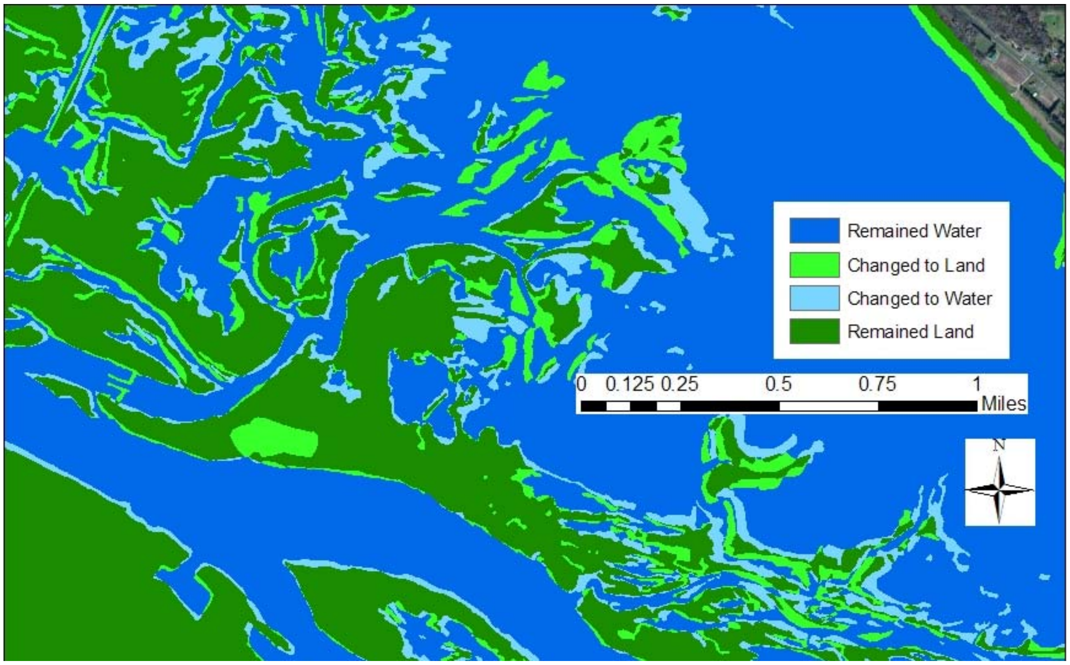

Figure 24. Change in land and water areas in the Indian Slough project area between the years 1989 and 2000 using LTRMP land cover data.

Winter Water Quality in Big Lake Bay

The Minnesota DNR Pool 4 LTRMP field station staff monitored winter water quality conditions in Big Lake Bay in early 1994 (Popp, 1994). Seven primary sites were sampled for dissolved oxygen concentration and water temperature on four dates. Sixteen sites were sampled on February 22 for dissolved oxygen concentration, water temperature, current velocity and current direction.

Snow cover occurred on the first three of the sampling dates, but warm temperatures on February 20 and 21 resulted in a lack of snow cover.

Dissolved oxygen concentrations were good, with the lowest concentration of 7.2 mg/l found near the bottom on January 24.

Water temperatures were low for lentic fishes, ranging between 0.0 °C and 2.5 °C near the bottom on February 22. Most water temperature measurements were between 0.0°C and 1.1°C.

Current velocities in Big Lake Bay were fairly low on February 22, ranging from 0.01 to 0.04 m/s.

Water Quality in Big Lake

Water quality in Big Lake has been monitored since 1993 by the LTRMP Minnesota DNR Pool 4 field station by both stratified random sampling and at a fixed station at the outlet of Big Lake. Dissolved oxygen measured at the outlet of Big Lake has remained above 5 mg/l except for two samples in the winter of 2010 (Figure 25). Water temperature at the same station ranged between a high of 30°C in the summer to 0°C in winter, characteristic of a flowing water location in the river.

LTRMP stratified-random sampling in Pool 4 contiguous backwaters (including Big Lake Bay) found that summer dissolved oxygen concentrations have been good, averaging above 5 mg/l (Figure 26). Summer water temperatures in the Pool 4 contiguous backwater areas were generally in the range of 22°C to 27°C (Figure 27).

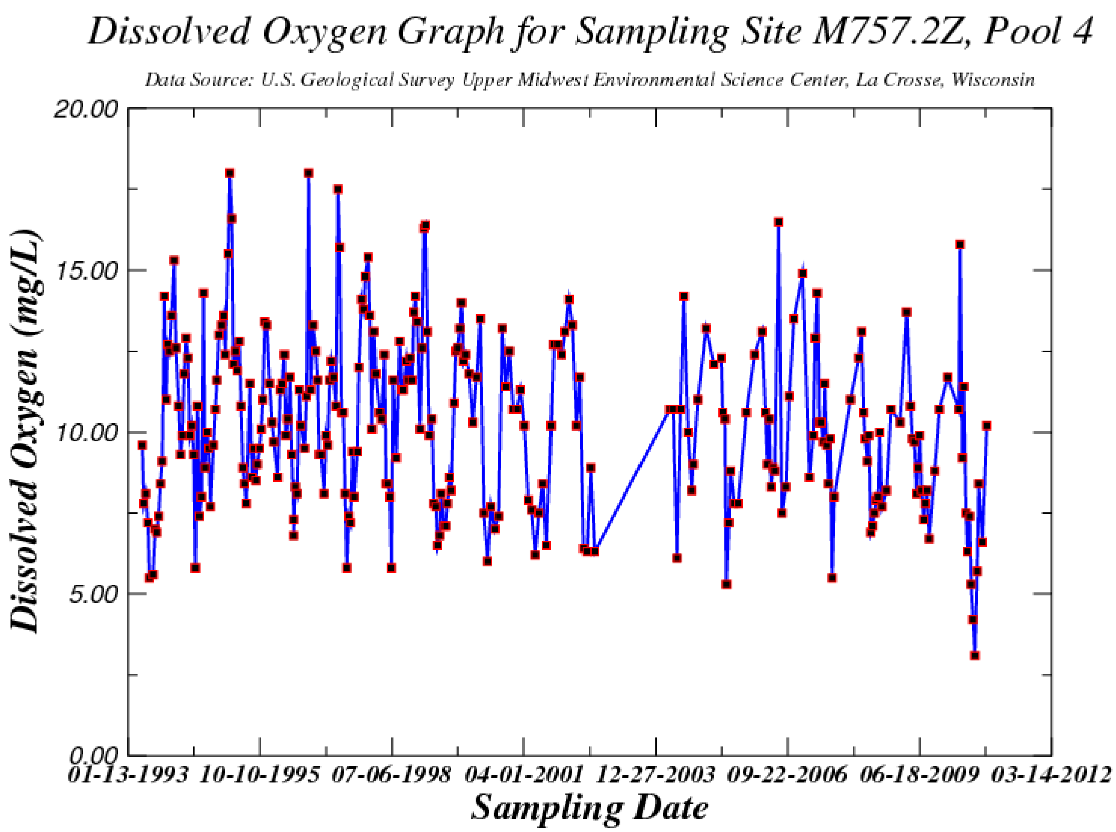

Figure 25. Dissolved oxygen concentration at an UMRS EMP Long Term Resource Monitoring Program (LTRMP) sampling station at the outlet of Big Lake, Pool 4 April 1993 – November 2010.

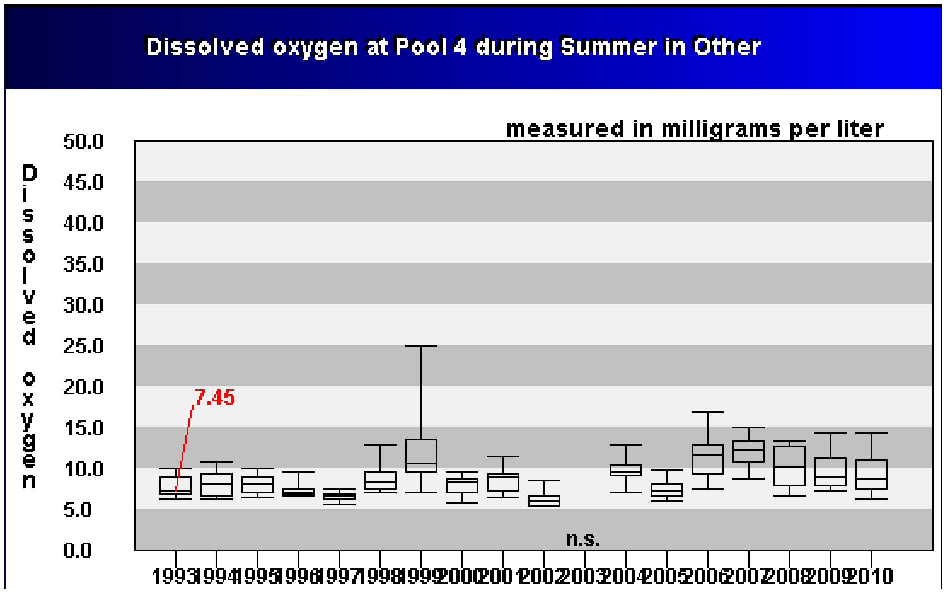

Figure 26. Dissolved oxygen concentration in Pool 4 contiguous backwaters at LTRMP stratified-random sampling locations (including Big Lake Bay) during summer 1993 – 2010.

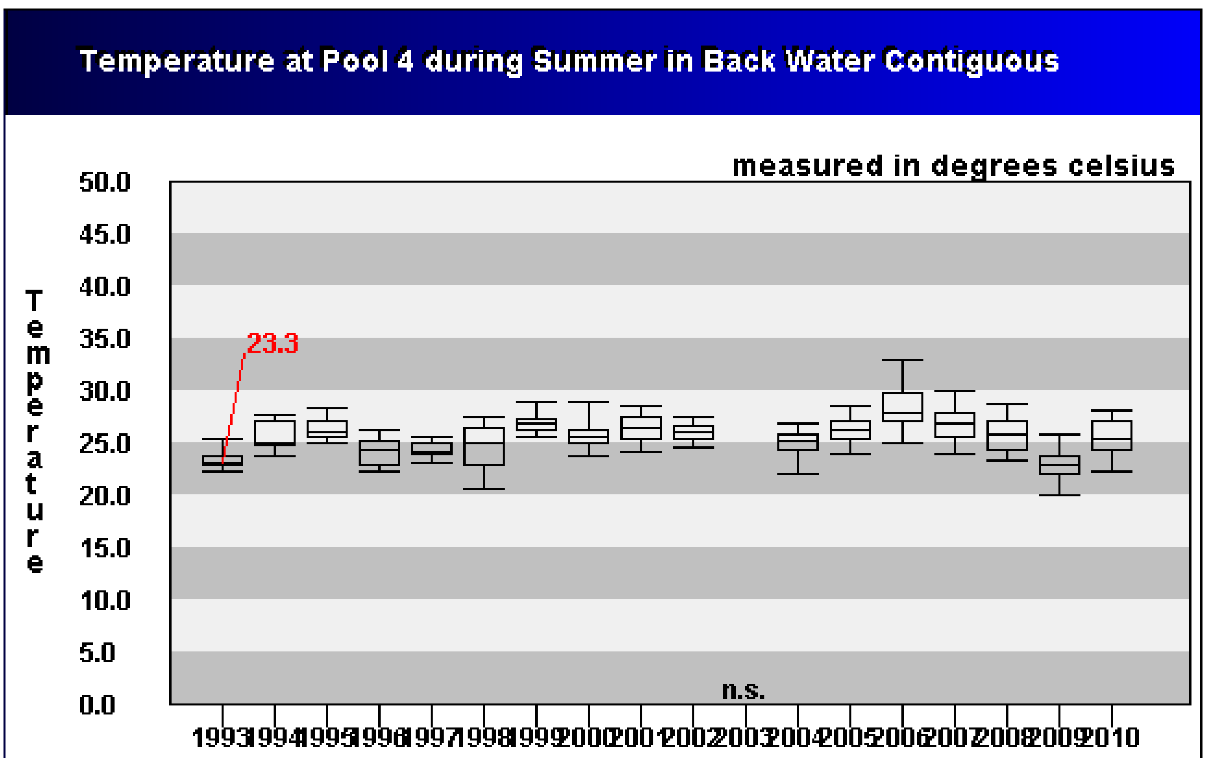

Figure 27. Water temperature in Pool 4 contiguous backwaters at LTRMP stratified-random sampling locations (including Big Lake Bay) during summer 1993 – 2010.

Aquatic Vegetation

Color infra-red aerial photographs from 1975, 1989, 1991-1994 and 1996 were interpreted and digitized to examine changes in aquatic vegetation in Big Lake (Dieck and Tyser 1999). Successional changes (from submersed vegetation to emergent and from emergent to terrestrial) were not observed. In Big Lake, open water increased from 211 ha in 1975 to 286 ha in 1996. There was no apparent effect of the HREP project on vegetation in Big Lake.

Fishery Surveys

The WIDNR (Brecka 1997) conducted electrofishing and fyke netting in August and October 1994 and in April 1995 to survey the fish community in Indian Slough in the vicinity of the riffle structures. They did not sample fish in the vicinity of the partial closing structure, the wood installations or in Big Lake Bay. They found a diverse fish community in Indian Slough, but a comparison of catch per unit of effort or species richness cannot be made to the Lucchesi and Benjamin 1988 results with the information provided. It may be possible to more closely examine the original fishery survey data to do a pre-to-post-project comparison.

6.5 Present Habitat Conditions

River discharge has been high in 2010 and 2011. Despite the high water, aquatic vegetation in the project area is abundant. The percent frequency of occurrence of submersed aquatic vegetation (SAV) in 2010 was the highest since 1986 (LTRMP Aquatic Vegetation Annual Summary 2010). Lower Pool 4 had a nearly 80% frequency of occurrence of SAV in the stratified random sampling sites in 2010. Rooted floating leaf and emergent vegetation remained relatively unchanged in upper and lower Pool 4 between 2009 and 2010.

According to Brian Brecka, WIDNR Fisheries Manager (personal communication July 19, 2011), Big Lake has changed over recent years to become more lentic and less riverine with abundant vegetation. There doesn’t seem to be much suitable winter habitat for lentic fishes remaining in Big Lake. The enlarged Catfish Slough has resulted in more flow through the Rice Lake part of Big Lake, lowering water temperatures and rendering that former wintering area for lentic fishes unsuitable. The HREP project dredge cut seems to be one of the few areas with suitable winter habitat for lentic fishes in Big Lake.

Also according to Brecka, much of the wood originally installed on the channel borders of Indian Slough appears to have deteriorated, although the anchoring rock is still visible. We do not know about the fate of the wood and brush crib structures originally installed. Indian Slough still has a variety of water depths, substrate, and hydraulic conditions.

The areas planted with prairie vegetation on Crats Island in 1993 remain vegetated with native grasses and forbs. The burr oak trees planted there also survived and are now good-sized trees.

6.6 Project-Induced Habitat Changes

The project significantly changed habitat conditions in Indian Slough, Big Lake (including Big Lake Bay), and parts of Crats Island.

The partial closing structure reduced flow down Indian Slough and through Big Lake. In addition to reducing flow, the partial closing structure also has reduced the movement of bed load sand into the upper end of Big Lake, part of the ongoing growth of the Chippewa River delta.

The closing structure on Indian Slough reduced the hydraulic exchange rate through Big Lake. The reduced hydraulic exchange rate did not result in warmer winter water temperatures or winter oxygen depletion in Big Lake. There is still considerable flow through Indian Slough and Big Lake during winter.

The riffle structure and the wood installations further modified Indian Slough channel habitat, increasing the amount of hard substrate and diversity of depth and hydraulic conditions for a diverse community of lotic fishes.

The dredge cut in Big Lake Bay provides a 4 to 5 ft deep area with suitable winter habitat conditions for lentic fishes.

Placement of fine material from Big Lake Bay on parts of Crats Island and planting native vegetation changed approximately 10 acres of bare sand dredged material deposit to vegetated island habitat. See Appendix A for a detailed assessment of the planted areas.

6.7 Other Habitat Changes in the Project Area

Dredged material continues to be added to the Crats Island placement site as part of routine channel maintenance. Aquatic vegetation in lower Pool 4 and other parts of the UMR has been abundant in recent years.

7 Project Evaluation

7.1 Construction and Engineering

7.1.1 Partial Closing Structure

The partial closing structure was constructed based on a re-entrant culvert design that results in eddies on either side of the entrance. A flow separation zone occurs between the side eddies and water entering the structure, reducing flow through the structure. This design has proven effective in reducing flows into Indian Slough. A scour hole developed downstream of the structure, providing a diversity of depth and hydraulic conditions in Indian Slough. The structure has remained stable since constructed.

The closing structure opening was directed at bank on Crat's Island. This required rock to stabilize eroding shoreline.

7.1.2 Rock Riffles

The constructed rock riffles have remained stable since constructed. Scour holes have developed downstream of them, providing a variety of depth, substrate and hydraulic conditions in Indian Slough. The north-west rock tie-in to the bank on the downstream riffle is experiencing some erosion behind it (Baylor 2007). This should be monitored and repaired if it continues.

7.1.3 Wood Installations

The anchored tree installations appear to have deteriorated over time. Parts not visible underwater may remain in place. The rock pile anchoring points are still visible. The fate of the wood and brush crib installations is unknown.

7.1.4 Rock Liners to Stabilize Channels

The rock liners placed to stabilize the entrances to Catfish Slough and Robinson Lake were not effective in preventing enlargement of those channels over time. The rock was flanked and the channels enlarged. Scour holes developed below the rock liner installations, effectively enlarging the channel cross sections.

7.1.5 Whorehouse Slough Dredging

Fill material for the closing structure was obtained from Whorehouse Slough, deepening that small channel using a small shallow-draft hydraulic dredge. The dredging improved small boat access from the Highway 25 boat landing to Indian Slough. Whorehouse Slough has since filled in so that it is navigable only by shallow draft boats.

7.1.6 Big Lake Bay Dredging

The dredge cut in Big Lake Bay appears to have filled in somewhat since 1993, but the dredge cut area remains about 4 to 5 feet deep, deeper than the surrounding parts of Big Lake Bay. The fine material provided soil for re-vegetating parts of the Crats Island dredged material placement site.

7.1.7 Crats Island Vegetation Plantings

The native prairie vegetation and trees planted on the fine material placed on Crats Island grew well and have persisted. Controlled burns done in 1997 and 1998 probably helped the native species become established. Additional controlled burns should be done in the future. See Appendix A for a detailed assessment of the planted areas on Crats Island.

7.2 Costs

The cost for Indian Slough construction by the Corps was $722,000; funded through the Corps operation and maintenance budget for the 9-Foot Channel Navigation Project. Contract dredging of Big Lake Bay dredging was $266,000; funded through the EMP. Tree and native prairie vegetation planting by the Corps cost approximately $6,000; funded through the EMP. Total project construction cost was $994,000.

The U.S. Fish and Wildlife Service spent $2,379 on two prescribed burns and periodic inspections of the project. There have been no other operation and maintenance costs or costs for rehabilitation or repairs. Costs of monitoring have not been reported.

This project was a bargain for the EMP, making effective use of Corps O&M funding. The project has not been costly to operate or maintain.

7.3 Ecological Effectiveness

7.3.1 Aquatic Resources

The partial closing structure reduced water and bed sediment inflow into Big Lake, effectively reducing the rate of Chippewa River delta growth into upper Big Lake.

The reduced flow into Indian Slough and Big Lake has not resulted in warmer winter water temperatures or dissolved oxygen depletion in Big Lake. The relatively high water exchange rate in Big Lake makes most of the lake too cold and with sufficiently high current velocities to render most of the lake unsuitable winter habitat for lentic fishes.

The partial closing structure, the rock riffles, and the wood installations increased the diversity of channel habitat conditions in Indian Slough. Indian Slough provides a good mix of habitat conditions for macroinvertebrates and lotic fishes.

The dredged area in Big Lake Bay has provided suitable winter habitat for lentic fishes.

7.3.2 Floodplain Resources

Conversion of 10 acres of the Crats Island dredged material placement site to native vegetation has been a positive change in island habitat.

7.3.3 Attainment of Project Objectives

Table 4. Indian Slough project objectives and degree of attainment.

Objectives	Degree of Attainment
Reduce rate of conversion of aquatic habitat to land in Big Lake delta area by 50%	- Post project water to land change has been relatively minor - Flow of water and bed load sediment through Indian Slough was reduced by approximately 52%
Maintain 5 mg/l D.O. summer and winter in at least 15% of Big Lake Bay	- D.O. is good in Big Lake Bay during summer and winter
Enhance habitat in 11 acres of Indian Slough for lithophilic fish species	- Indian Slough geometry has been fairly stable since project construction. - There is a variety of water depth, substrate and hydraulic conditions in Indian Slough. - The partial closing structure and the rock riffles have been stable since construction. - Rock substrate remains exposed in the riffles. - The wood installations may have deteriorated over time. Further inspection will be done to determine how much remains.
Restore/maintain Big Lake Bay as centrarchid fish habitat	- 11 acres of Big Lake Bay was deepened to 5 ft by dredging - The dredged area has filled only slightly since 1993 - The dredged area provides suitable winter habitat for lentic fishes

7.4 Public Acceptance

Reports from the state resource managers indicate that the project has been generally well accepted by the public. The partial closing structure is navigable by boats however current velocities through it are high during higher river discharge.

Sport fishing in Indian Slough is good for smallmouth bass, white bass, walleyes and channel catfish. The dredged area in Big Lake Bay provides winter habitat for panfish and ice fishing opportunity. The Rice Lake area of Big Lake has declined as a popular ice fishing area, apparently due to increased flow through that area from Catfish Slough.

Big Lake has abundant aquatic vegetation, provides habitat for many migrating birds, and provides wildlife viewing opportunities for the public. The U.S. Fish and Wildlife Service has designated most of Big Lake south of Indian Slough as a closed area during fall waterfowl migration season.

8 Lessons Learned and Recommendations for Similar Projects

The following is based on discussions with biologists and engineers from USACE, WIDNR, MNDNR, and the USFWS.

8.1 Partial Closing Structure

The partial closing structure has been effective in reducing flow of water and bed sediment through Indian Slough. The re-entrant culvert design with the upstream-pointing legs works well.

The partial closing structure is an obviously constructed artifact in the river visible from the water and from the Highway 25 bridge. It would be possible to fill between the upstream-extending legs of the structure and the shoreline on either side, cap the areas with fine material and plant the areas with native floodplain trees. This would make the structure less apparent and would provide additional channel border floodplain habitat. However, filling all the way to the upstream end of the rock legs would reduce the effectiveness of the re-entrant design.

The area upstream of the closing structure has filled with sediment, resulting in some deep-water habitat loss and reducing navigability for recreational boats. Dredging a channel leading to the closing structure could be done, however this channel would quickly fill with sediment.

It would have been possible to pre-dredge the scour hole below the partial closing structure to reduce downstream sedimentation.

The partial closing structure design appears to be applicable to other secondary channels on the UMR where the intent is to limit lateral hydrologic connectivity between the main channel and backwater areas. Closing structures can be configured to look more like a channel between islands, rather than two straight parallel lines of rock

8.2 Rock Riffles

The rock riffles constructed in Indian Slough have remained stable since construction. Scour holes have formed downstream of the rock riffles. The rock in the riffle structures remains exposed. The rock riffles provide a variety of channel habitat for lithophilic macroinvertebrate and fish species. Rock riffles like those constructed in Indian Slough are applicable to other secondary and tertiary channels on the UMR where hard substrate is scarce.

8.3 **Rock Liners on Catfish Slough and Entrance to Robinson Lake**

The rock liners constructed on these channels did not reduce flow or hold it constant. If a channel is getting larger with time due to erosion throughout its length, simply placing a rock liner at the head of the channel doesn't reduce flows over time. If the intent is to reduce lateral connectivity, a more substantial partial closing structure like the one on Indian Slough is needed to reduce flow through the channels. Examples of other partial closure structures that have successfully reduced flow include the one at Site 6 at Lansing Big Lake, or Site 5 in Peterson Lake, both of which are EMP projects.

8.4 **Dredging in Big Lake Bay**

The dredge cut in Big Lake Bay has been effective in providing winter habitat for lentic fishes and sport fishing opportunity. The dredged area has not filled in appreciably since project construction in 1993.

8.5 **Native Vegetation Planting**

The native prairie vegetation and trees planted on the fine material placed on Crats Island grew well and persisted. Native prairie and oak savanna vegetation on the UMRS is primarily on high parts of the floodplain and on the terraces. Future plantings should be done with locally-obtained native seed and an attempt should be made to mimic the species composition of the remaining native prairie and oak savanna areas on the UMRS. These areas are fire-dependant ecosystems, so controlled burns should be done every 3 to 5 years to maintain them. Additional lessons learned and recommendations about native vegetation planting on dredged material are in Appendix A.

8.6 **Other Potential Improvements for Habitat Conditions in the Project Area**

Resource managers have provided the following recommendations:

- Excavate a channel leading to the partial closing structure
- Fill between the rock "arms" of the closing structure and the channel banks, cap with fine material and plant with native vegetation
- Conduct forest management in the project area to restore a diverse native floodplain forest
- Dredge part of Truedale Lake to provide winter habitat for lentic fishes
- Construct a partial closing structure on Catfish Slough to reduce flow into Big Lake and improve winter fish habitat
- Inspect the wood installations in Indian Slough, replace them if needed
- Conduct controlled burns on the planted prairie areas on Crats Island every 3 to 5 years.

8.7 **Recommendations on Project Monitoring**

The following recommendations are based on discussions with Corps EMP biologists and engineers and with state and U.S. Fish and Wildlife Service partners:

- Obtain "as built" digital elevation or bathymetric surveys on all project features immediately after construction
- Carefully design pre-and post-construction biological monitoring experiments to enable quantitative evaluation of changes in abundance of vegetation, macroinvertebrates and fish, with a focus on the project objectives.
- Include detailed monitoring plans, cost estimate and schedule in the project DPRs.
- Maintain an electronic library of EMP HREP DPRs, monitoring plans, results, and Project Evaluation Reports on an EMP Decision Support System (DSS) accessible via the Internet.
- Conduct project inspections at least every two years and after major floods.

References

Baylor, S. 2007. Indian Slough HREP Project annual inspection report. U.S. Fish and Wildlife Service. Upper Mississippi River National Wildlife and Fish Refuge. Winona, Minnesota.

Belanger. K., D. Dieterman, and T. Deys. 1990. Water quality survey of Big Lake Bay. Data provided to the U.S. Army USACE, St. Paul District. USFWS Environmental Management Technical Center, LaCrosse, Wisconsin.

Benjamin, R. and M. J. Talbot 1985. Determine angler harvest and exploitation, total mortality and population estimates of largemouth bass in Big Lake (Pool 4) of the Mississippi River. Mississippi River Work Unit Annual Report, 1984-85. Wisconsin Department of Natural Resources, LaCrosse, Wisconsin. (Cited in USACE 1994).

Brecka, B. 1997. Memorandum: Indian Slough Performance Evaluation. Wisconsin Department of Natural Resources, LaCrosse, Wisconsin.

Dieterman, D. 1991. Big Lake Bay HREP Pre-project monitoring of winter dissolved oxygen, water temperature, and current velocity. Long Term Resource Monitoring Program Field Station. Minnesota Department of Natural Resources, Lake City, Minnsota. Letter report to the St. Paul District, U.S. Army USACE April 12, 1991.

Lucchesi, D. and R. Benjamin. 1988. Pre-project fishery inventory of Big Lake - Indian Slough, Pool 4. August 1987 – April 1988. Wisconsin Department of Natural Resources, LaCrosse, WI.

Popp, W. 1994. Post-project monitoring of winter dissolved oxygen, water temperature, and current velocity for the Big Lake Bay Habitat Rehabilitation and Enhancement Project (HREP) on Navigation Pool 4 of the Upper Mississippi River.

Regional Support Team and Upper Impounded Reach Planning Team. 2010. Reach Plan for UMRS Ecosystem Restoration Upper Impounded Floodplain Reach. St. Paul District, U.S. Army Corps of Engineers. St. Paul, Minnesota. On-line at: http://www2.mvr.usace.army.mil/UMRS/NESP/Documents/UMRS%20Ecosystem%20Restoration%20Objectives%202009%20-%20Appendix%20A%20(1-20-2011).pdf

Schellhaass, S. and J. Sullivan. 1988. Monitoring of dissolved oxygen, temperature and light in selected backwaters of the Upper Mississippi River, Wisconsin Department of Natural Resources, unpublished report, LaCrosse, WI.

Talbot, M. J. 1981. Big Lake inventory. Mississippi River Work Unit Annual Report, 1980-81. Wisconsin Department of Natural Resources, LaCrosse, WI.

U.S. Army Corps of Engineers (USACE). 1990. Indian Slough Habitat Rehabilitation and Enhancement Project. Definite Project Report/Environmental Assessment. St. Paul District, U.S. Army USACE. St. Paul, Minnesota.

U.S. Army Corps of Engineers (USACE). 1994. Indian Slough Habitat Rehabilitation and Enhancement Project. Operation and Maintenance Manual. St. Paul District, U.S. Army USACE. St. Paul, Minnesota.

Appendix A
Crats Island Vegetation Assessment

Appendix A

Crats Island Vegetation Assessment

August 25, 2011
Megan Kranz-McGuire

Introduction

Two areas on Crats Island were seeded with native prairie grasses and forbs in 1994. Bur oak seedlings were planted as well. Although the two areas are to the east and west of a dredge material placement site, they are referred to as the North Area and South Area, the North Area being upstream of the placement site, and the South Area being downstream of the placement site (see figure 1). Vegetation was monitored in 1995, 1997, and 1999, and adequate soil coverage was noted. On August 23rd, 2011 staff from the La Crescent COE Natural Resources office visited the site to conduct follow-up vegetation monitoring of vegetation coverage and plant community composition.

History

From the report "Summary of Vegetation Changes on Dredged Material and Environmental Management Program Sites in the St. Paul District, Corps of Engineers," Anfang and Wege, 2000:

In 1994, the area was drill seeded with the following mixture and mulched:

- big bluestem *(Andropogon gerardi)*
- little bluestem *(Andropogon scoparius)*
- Indian grass *(Sorghastrum nutans)*
- switchgrass *(Panicum virga tum)*
- side oats grams *(Bouteloua curtipendula)*
- prairie dropseed *(Sporobolus heterolepsis)*
- perennial rye *(Lolium perenne)*

A minimum of four of the forbs listed below were seeded:

- black-eyed Susan *(Rudbeckia hirta)*
- yellow coneflower *(Ratiblda columnifers)*
- rough blazing star *(Liatris aspera)*
- prairie clovers *(Petalostemun sp.)*
- leadplant *(Amorpha canescens)*
- stiff tickseed *(Coreopsis palmata)*

At a later date, rootstocks of the following native wildflowers were also planted:

- early sunflower *(Heliopsis helianthoides.)*
- compass-plant *(Silphium laciniatum)*
- prairie blazing start *(Liatris pycnostachya)*
- rough blazing star *(Liatris aspera)*
- old field goldenrod *(Solidago nemoralis)*
- purple coneflower *(Ratibida columnifera)* (sic)

Bur oak seedlings were planted in the seeding area and protected with tree tubes.

Appendix A

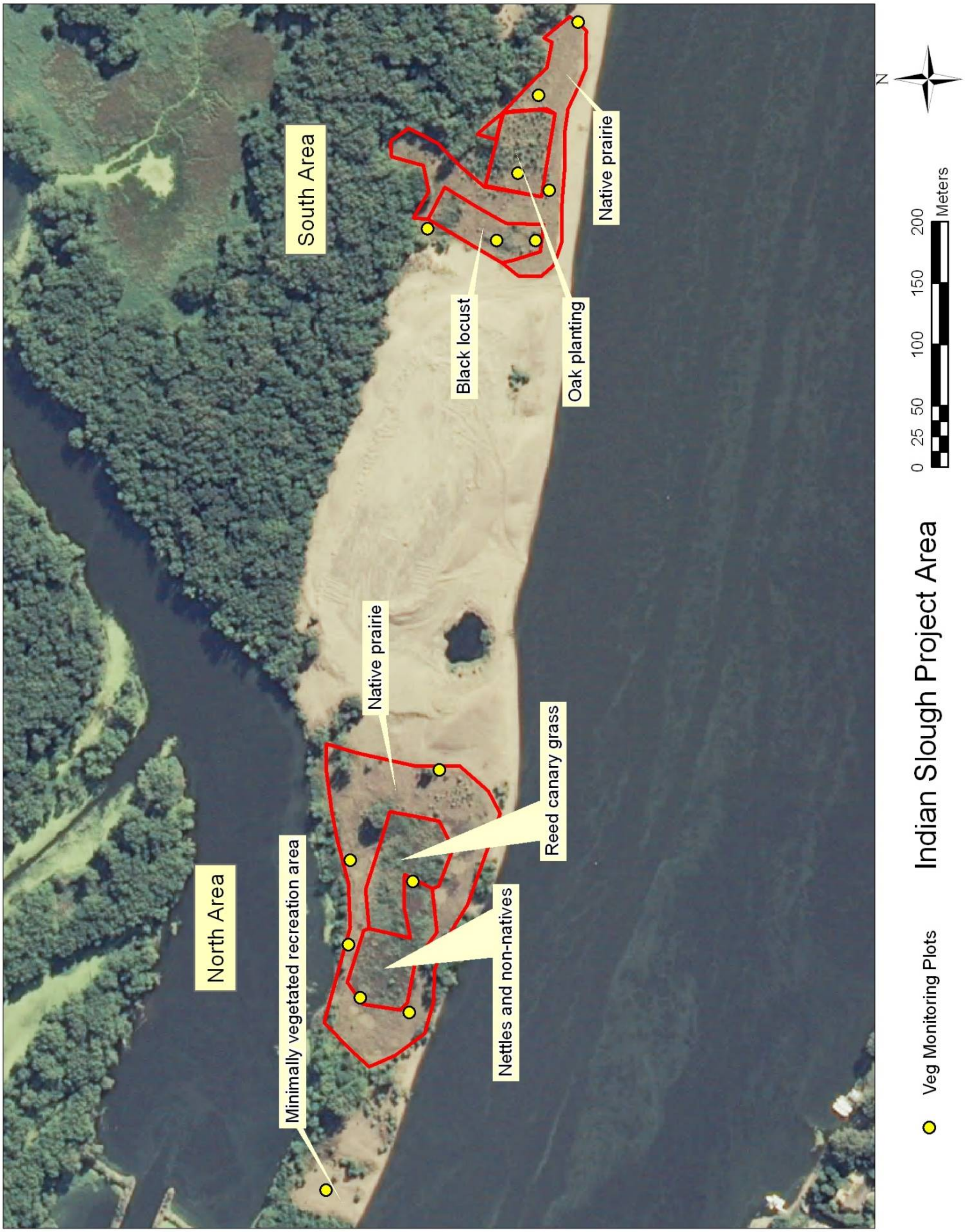

Figure 1.

Vegetation Assessment

Methodology

Seven plots were randomly placed on both the north and south areas. A one-meter-square quadrat was placed on each plot, and vegetation composition, ground coverage, and dominance were measured within the quadrat. Only vegetation rooted within the quadrat was recorded; plants hanging over the quadrat but rooted nearby were not counted. Coverage of each species was rounded to the nearest 10%. Robel pole readings were taken at each plot to determine the height: density ratio of the vegetation. Species not found within the plot, but randomly encountered on the site are noted in the species list. However, we did not conduct a thorough survey of the entire area, so the species list must be viewed as very incomplete. The plots showed very different success rates of native vegetation establishment distributed in a clear spatial pattern. Plot data is summarized for each area, but the differences between plots tells the real story about native vegetation success on the site.

Summarized Plot Data from 2011

Total vegetation coverage, Robel readings, and individual species coverage were collected for each plot. Please consult Anfang and Wege (2000) for formulas used to calculate dominance, frequency, relative dominance, relative frequency, and importance. The average cover on the North Area was 88%, and the Robel readings averaged 5.8. The average cover on the South Area was 99%, and the Robel readings averaged 3.5. The vegetation coverage was excellent (90-100%) on every plot except one, which may not have been included in the original planting. Robel readings were high on many plots. Areas dominated by big bluestem typically had the highest Robel scores, while areas dominated by non-natives such as reed canary grass or smooth brome had much lower scores, simply due to the height of the species.

Appendix A

Species dominance for the two areas is summarized below:

North Area Species	Total % Cover of the Species	Dominance	Relative Dominance
Big Bluestem	220	31	22
Reed Canary Grass	140	20	14
Stinging Nettle	100	14	10
Grass-- thin leaves	50	7	5
Missouri Goldenrod	50	7	5
Smooth Brome	50	7	5
Butter and Eggs	30	4	3
Poison Ivy	30	4	3
Sideoats Gramma	30	4	3
Black-eyed Susan	20	3	2
Canada Thistle	20	3	2
Common Evening Primrose	20	3	2
Foxtail	20	3	2
Grass-- purple	20	3	2
Indian Grass	20	3	2
Sedge	20	3	2
Switchgrass	20	3	2
American Elm	10	1	1
Canada Rye	10	1	1
Canada Goldenrod	10	1	1
Cheat Grass	10	1	1
Common Ragweed	10	1	1
Devil's Beggartick	10	1	1
European Buckthorn	10	1	1
Heartleaf Four O'clock	10	1	1
Hoary Alyssum	10	1	1
Marestail	10	1	1
Ribseed Sandmat	10	1	1
Stickseed	10	1	1

South Area Species	Total % Cover of the Species	Dominance	Relative Dominance
Big Bluestem	320	46	37
Smooth Brome	270	39	31
Little Bluestem	100	14	11
Crown Vetch	90	13	10

Canada Thistle	20	3	2
Canada Wild Rye	20	3	2
Cheat Grass	20	3	2
Grass-- thin leaves	20	3	2
Birdsfoot Trefoil	10	1	1

Species frequency for the two areas is summarized below:

North Area	**Frequency**	**Relative Frequency**
Big Bluestem	57	10
Butter and Eggs	43	7
Canada Thistle	29	5
Foxtail	29	5
Grass-- thin leaves	29	5
Missouri Goldenrod	29	5
Reed Canary Grass	29	5
Sedge	29	5
Stinging Nettle	29	5
American Elm	14	2
Black-eyed Susan	14	2
Canada Rye	14	2
Canada Thistle	14	2
Canada Goldenrod	14	2
Cheat Grass	14	2
Common Evening Primrose	14	2
Common Ragweed	14	2
Devil's Beggartick	14	2
European Buckthorn	14	2
Grass-- purple	14	2
Heartleaf Four O'clock	14	2
Hoary Alyssum	14	2
Indian Grass	14	2
Marestail	14	2
Poison Ivy	14	2
Ribseed Sandmat	14	2
Sideoats Gramma	14	2
Smooth Brome	14	2
Stickseed	14	2
Switchgrass	14	2

South Area	**Frequency**	**Relative Frequency**
Smooth Brome	57	29

Big Bluestem	43	21
Birdsfoot Trefoil	14	7
Canada Thistle	14	7
Canada Wild Rye	14	7
Cheat Grass	14	7
Crown Vetch	14	7
Grass-- thin leaves	14	7
Little Bluestem	14	7

Species importance for the two areas is summarized below:

North Area	**Importance Value**
Big Bluestem	16.0
Reed Canary Grass	9.5
Stinging Nettle	7.5
Butter and Eggs	5.1
Grass-- thin leaves	4.9
Missouri Goldenrod	4.9
Smooth Brome	3.7
Canada Thistle	3.4
Foxtail	3.4
Sedge	3.4
Poison Ivy	2.7
Sideoats Gramma	2.7
Black-eyed Susan	2.2
Common Evening Primrose	2.2
Grass-- purple	2.2
Indian Grass	2.2
Switchgrass	2.2
American Elm	1.7
Canada Wild Rye	1.7
Canda Goldenrod	1.7
Cheat Grass	1.7
Common Ragweed	1.7
Devil's Beggartick	1.7
European Buckthorn	1.7
Heartleaf Four O'clock	1.7
Hoary Alyssum	1.7
Marestail	1.7
Ribseed Sandmat	1.7
Stickseed	1.7

Appendix A

South Area	Importanc e Value
Smooth Brome	29.8
Big Bluestem	29.1
Little Bluestem	9.3
Crown Vetch	8.7
Canada Thistle	4.7
Canada Wild Rye	4.7
Cheat Grass	4.7
Grass-- thin leaves	4.7
Birdsfoot Trefoil	4.1

List of Plants Noted during 2011 Vegetation Assessment (not a complete survey of the area)

Common Name	Scientific Name
American Elm	*Ulmus americana*
Big Bluestem	*Andropogon gerardii*
Birdsfoot Trefoil	*Lotus corniculatus*
Black Locust*	*Robinia pseudoacacia*
Black-eyed Susan	*Rudbeckia hirta*
Bur Oak*	*Quercus macrocarpa*
Butter and Eggs	*Linaria vulgaris*
Canada Thistle	*Cirsium arvense*
Canada Wild Rye	*Elymus canadensis*
Canda Goldenrod	*Solidago canadensis*
Cheat Grass	*Bromus tectorum*
Common Evening Primrose	*Oenothera biennis*
Common Ragweed	*Ambrosia artemisiifolia*
Crown Vetch	*Coronilla varia*
Devil's Beggartick	*Bidens frondosa*
European Buckthorn	*Rhamnus cathartica*
Foxtail	*Setaria viridis*
Heartleaf Four O'clock	*Mirabilis nyctaginea*
Hoary Alyssum	*Berteroa incana*
Indian Grass	*Sorghastrum nutans*
Little Bluestem	*Schizachyrium scoparium*
Marestail	*Conyza canadensis*
Missouri Goldenrod	*Soliday missouriensis*
Poison Ivy	*Toxicodendron radicans*
Prairie Dropseed*	*Sporobolus heterolepsis*
Purple Prairie Clover*	*Dalea purpurea*
Reed Canary Grass	*Phragmites arundinacea*
Ribseed Sandmat	*Chamaesyce glyptosperma*

Round-headed Bush Clover*	*Lespedeza capitata*
Sedge	*Carex spp.*
Siberian Elm*	*Ulmus pumila*
Sideoats Gramma	*Bouteloua curtipendula*
Smooth Brome	*Bromus inermis*
Stickseed	*Hackelia virginiana*
Stinging Nettle	*Urtica dioica*
Sweet Everlasting*	*Gnaphalium obtusifolium*
Switchgrass	*Panicum virgatum*
Virginia Wild Rye*	*Elymus virginiana*

*not found in a plot, but present on site

Seeding and Planting Success

The list of most important species includes big bluestem in both areas, along with invasive grasses (smooth brome and reed canary grass) and low-quality forbs (stinging nettle, butter and eggs, crown vetch). Big bluestem and little bluestem ranked high in the South Area, however little bluestem was present only between the seeded area and the open sand and was absent from the majority of the site.

Big bluestem was the only seeded species that was overwhelmingly successful, and only in certain areas. In the areas where it established well, it forms thick monocultures that exclude native forbs, as wells as invasive grasses. All native grasses are established, but all species other than big bluestem have sparse distribution on both sites. These grasses include sideoats gramma, Indian grass, switchgrass, Canada wild rye, little bluestem, and prairie dropseed. Virginia wild rye was noted on the site, but was not included in the original seed mix. While big bluestem provides successful ground cover, a more even coverage of native grasses would be desirable for biodiversity.

The only seeded forbs that established are black-eyed Susan and purple prairie clover. We did not encounter any leadplant, rough blazing star, early sunflower, compass-plant, prairie blazing star, old field goldenrod, purple coneflower, or yellow coneflower. This is not surprising considering the seed mix quantities. Prairie seed mixes should include a high proportion of forbs and be planted in the fall if a restoration is to achieve the level of forb establishment required to replicate a native prairie. If soil stabilization is the only goal, it may not be worth adding such a small amount of forb seed to the seed mix, since they do not successfully establish at that seeding level. It is surprising that none of the planted forb rootstocks were found on the site, and the reasons for their failure it not clear. Lack of adequate moisture could be a factor. Three native prairie species of interest were found on the site, though they were not planted: Missouri goldenrod, sweet everlasting, and round-headed bush clover. These species were not widespread, but it is encouraging to see recruitment of additional forb species.

Both the North and South Areas had distinct patches of good and poor quality vegetation (see figure 1). In both areas, big bluestem formed a near-monoculture in a band around the outside of the site. Between the big bluestem and the open sand, patches of little bluestem were successful in some areas (see figures 2-4). Other native grasses and forbs were mixed amongst the big bluestem in this donut of prairie. The interiors of both areas were colonized almost exclusively by non-natives or undesirable natives, such as nettle. Smooth brome and reed canary grass form large monocultural patches in the center of each area. In the South Area, a young patch of black locust has been expanding into the planting. These trees will continue to expand and will shade out native grasses (figure 5). Siberian elms were also present on the perimeter of the grass. The oak planting in the South Area is successful as an open savanna planting (figure 6). Some trees are about twenty feet tall, while other are small re-sprouts. The larger trees may be able to withstand a burn soon.

To the west of the North Area, there are two open areas with little vegetation (see figure 7). These areas are heavily used for recreation. As there is no map of the precise original planting area, we cannot determine whether the area is bare due to human use or because it was never seeded. In any case, it suggests what the area might look like if it had not been capped with fine sediment and planted—a barren of sand with about 15% groundcover consisting of sparse grasses and sedges.

Figure 2. Indian grass and big bluestem in the South Area


Figure 3. Big bluestem with goldenrod in the foreground in the North Area


Figure4. Little bluestem growing on the edge of the dredge material placement area in the North Area


Figure 5. Black locust grove in the South Area


Figure 6. Bur oak planting in the South Area

Figure 7. Area used for recreation on the west side of the North Area

Conclusion and Management Recommendations

Big bluestem established successfully in a band around the outside of both areas. The dominance of invasive grasses in the center of the areas could be a result of overly mesic soil conditions due to excessively deep soil additions. Reed canary grass prefers wet conditions, and its presence at the highest elevation on the North Area would be surprising if the soil had a high proportion of sand. Little bluestem established successfully only at the very edge of the seeded areas where the soil was extremely sandy. As the Corps implemented revegetation projects over the years, better soil capping recommendations have been developed. If records of fine sediment placement quantities for this site exist, they should be reviewed to help define parameters for successful native vegetation establishment.

The serious absence of native forbs, including seeded and planted species, is a concern if wildlife habitat is a goal of this planting. The native grasses stabilize the soil very effectively, but a high proportion of forbs are desirable for many forms of wildlife, including birds and insects. The planting mix for this site was far too heavy on grass seed. To achieve plant communities that mimic natural prairies, seed mixes should consist of approximately a 1:1 ratio of grass to forbs (Dorner, 2002). Planting in fall also helps favor forb success, as does prescribed burning.

Certain management actions would enhance the existing native vegetation and prevent the loss of natives to invasives. Prescribed burns are highly recommended. In the South Area, burns should be conducted when the fire intensity will be low to prevent damage to the oaks. The patch of black locusts in the South Area should be removed or they will encroach on the native plantings. Management of other invasive such as reed canary grass, smooth brome, and Siberian elm would benefit the site. As the site is in a floodplain, invasive species will be continually reintroduced to the site. Therefore, long term control of invasive species must rely on establishing a resilient native plant community resistant to invasion so that chemical and physical removal efforts can be minimized. A diverse native plant community maintained by burning will be more effective at preventing re-invasion than attempts to control invasive species after they have become established.

In conclusion, this site offers valuable insight into effective soil parameters for native vegetation establishment. The two areas both contain patches of thick, successful native grasses, but also contain large areas completely colonized by invasives. Creating native plant communities that can resist invasive by non-natives is a challenge in any environment, but especially so in floodplains. The successful areas of this project offer hope that native plant communities can persist decades after establishment. By drawing lessons from this and other sites, we can develop more effective soil and planting methods that will make future plantings even more successful.

References

Anfang , R. & Wege, G. (2000), Summary of Vegetation Changes on Dredged Material and Environmental Management Program Sites in the St. Paul District, Corps of Engineers. US Army Corps of Engineers, St. Paul District.

Dorner, J. (2002). An Introduction to Using Native Plants in Restoration Projects. Plant Conservation Alliance, Bureau of Land Management, US Department of Interior. http://www.nps.gov/plants/restore/pubs/intronatplant/intronatplant.pdf