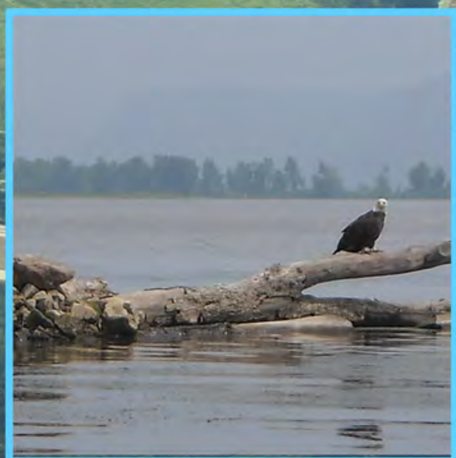
Upper Mississippi River Restoration
Environmental Management Program



US Army Corps of Engineers®

Environmental Design Handbook

December 2012

UPPER MISSISSIPPI RIVER RESTORATION
ENVIRONMENTAL MANAGEMENT PROGRAM
ENVIRONMENTAL DESIGN HANDBOOK

FOREWORD

Welcome to the 2nd Edition of the Upper Mississippi River Restoration – Environmental Management Program's (UMRR-EMP) Environmental Design Handbook. This revision captures the extensive lessons learned over the past 26 years during the formulation and construction of 54 habitat rehabilitation and enhancement projects benefiting nearly 100,000 acres of aquatic and floodplain habitat within the 1,200 miles of the Upper Mississippi River System.

This revision incorporates not only the engineering lessons learned during this period but it also shows the linkage between regionally adopted goals and objectives and the restoration techniques being used within the UMRR-EMP to meet those goals and objectives. Additionally, while the UMRR-EMP has utilized an adaptive management philosophy from its inception, this revision explores the UMRR-EMP's efforts to more explicitly apply adaptive management techniques to address restoration practices which continue to have elements of risk and uncertainty come.

The UMRR-EMP was authorized by Congress in the 1986 Water Resources Development Act. This authorization created the first large river ecosystem restoration program in the nation and as such opened the door to many new ecosystem restoration and engineering innovations.

The UMRR-EMP is a regional program encompassing three US Army Corps of Engineers Districts (St Louis, MO; Rock Island, IL; and St. Paul, MN) and five states (Illinois, Iowa, Michigan, Minnesota, and Wisconsin). All restoration efforts originate out of the three District offices. Each project is developed with a project sponsor, and the formulation of all projects is coordinated through multi-agency and multi-disciplinary teams working in the five states that comprise the UMRR-EMP.

This revised Environmental Design Handbook captures the current state of the art and science in large river ecosystem restoration efforts by the UMRR-EMP. It is intended to continue to ensure consistency and high quality restoration efforts over multiple offices and agencies covering 1,200 miles of navigable river. I hope that others working to restore large river ecosystems will also find it a useful guide to aid in their efforts.

Sincerely,

Marvin E. Hubbell, Regional Program Manager
Upper Mississippi River Restoration – Environmental Management Program

Executive Summary

The Upper Mississippi River Restoration Environmental Management Program (EMP) is successfully implementing innovative and effective habitat projects and conducting cutting-edge monitoring and research. First authorized in Section 1103 of the Water Resources Development Act of 1986, the EMP has made significant contributions to ensure that the Upper Mississippi River System remains a nationally significant ecosystem.

When the EMP began, Habitat Rehabilitation and Enhancement Project (HREP) designers implemented and refined construction techniques in ways not previously imagined. The intent was to improve habitat through site-specific modifications. Since 1986, the EMP's HREP component has evolved into a successful program that combines a broad range of construction techniques with approaches that strive to use or mimic natural riverine processes, providing benefits to the river at system, reach, pool and local scales.

Innovations and lessons learned in the HREP program have benefited not only the EMP, but also other programs on the Upper Mississippi River and throughout the United States where similar efforts are underway to preserve and restore habitat on large floodplain river systems. The EMP and the U.S. Army Corps of Engineers are internationally recognized leaders in such endeavors.

There has been significant documentation on individual HREPs, including feasibility level studies, as built construction drawings, operation and maintenance manuals, and performance evaluation reports. However, these reports have generally been project specific and often do not describe project lessons learned. This design handbook was created to describe project features common to HREPs.

Upper Mississippi River Restoration
Environmental Management Program

Acknowledgements

The U.S. Army Corps of Engineers would like to express its appreciation to the following Federal and State agencies and non-governmental organizations that contributed to this report. Their coordination efforts and document reviews were invaluable.

- **Illinois Department of Natural Resources**
- **Iowa Department of Natural Resources**
- **Minnesota Department of Natural Resources**
- **Missouri Department of Conservation**
- **Wisconsin Department of Natural Resources**
- **Natural Resources Conservation Service**
- **United States Environmental Protection Agency**
- **United States Fish and Wildlife Service**
- **United States Geological Survey**
- **Upper Mississippi River Basin Association**

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The U.S. Army Corps of Engineers solicited the service of the following individuals to author various sections of the *Upper Mississippi River Restoration Environmental Management Program Environmental Design Handbook.*

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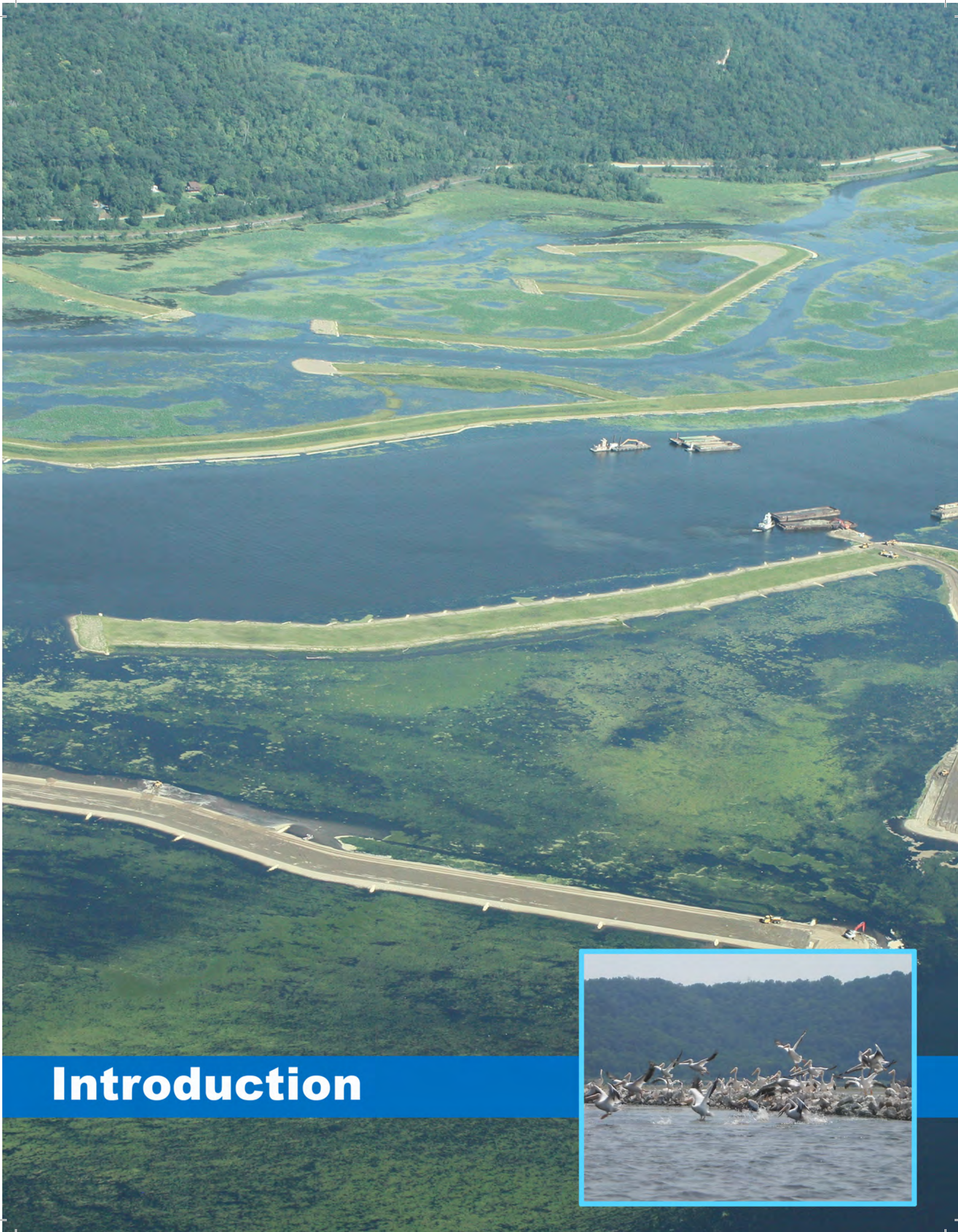

Introduction

UPPER MISSISSIPPI RIVER RESTORATION ENVIRONMENTAL MANAGEMENT PROGRAM ENVIRONMENTAL DESIGN HANDBOOK

INTRODUCTION

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INTRODUCTION

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INTRODUCTION

A. PURPOSE

The U.S. Army Corps of Engineers (Corps), with input from the Upper Mississippi River Restoration-Environmental Management Program (UMRR-EMP) partners, developed the Environmental Design Handbook to document the array of restoration tools and lessons learned to aid in the design of future Habitat Rehabilitation and Enhancement Projects (HREP). These restoration tools include shoreline protection, island creation, water level management, backwater dredging, secondary channel modifications and river training structures, aeration, and floodplain and tributary restoration. The 2006 Environmental Design Handbook[1] details the project features, design methodologies, and lessons learned since UMRR-EMP's inception. This 2012 Handbook includes an update to the 2006 information, captures new information about innovative restoration tools, and provides additional information on planning and ecosystem objectives.

B. UMRR-EMP AUTHORIZATION & DOCUMENTATION

The UMRR-EMP was authorized by Congress in Section 1103 of the Water Resources Development Act (WRDA) of 1986 (Public Law 99-662), as amended[2]. The Corps is required by the authorizing language in WRDA to report the status of the UMRR-EMP to Congress at a specific frequency. Three reports to Congress have been completed to date and provide significant information regarding the UMRR-EMP, authorities and outcomes. These documents provide an excellent source of information regarding the history of the UMRR-EMP Program.

U.S. Army Corps of Engineers, *Upper Mississippi River Restoration Environmental Management Program Report to Congress*, 2010. This evaluation discusses UMRR-EMP's considerable accomplishments and s how 25 years of evolving legal authorities, management actions, and policy decisions have shaped the UMRR-EMP.

U.S. Army Corps of Engineers, *Upper Mississippi River Restoration Environmental Management Program Report to Congress*, 2004. This is the second formal evaluation of the UMRR-EMP which provides an opportunity to step back and take a critical look at the collective impact of the legal authorities, management actions, and policy decisions that have shaped the UMRR-EMP.

U.S. Army Corps of Engineers, *Upper Mississippi River System Environmental Management Program Report to Congress*, 1997. This report contains overarching conclusions drawn with respect to the UMRR-EMP outputs, strengths and weaknesses and the future needs of the UMRS.

In 2003, an effort to ensure that planning and sequencing of HREPs occurred in a consistent manner was undertaken. These efforts were documented in the U.S. Army Corps of Engineers, *Habitat Rehabilitation and Enhancement Project (HREP) Planning and Sequencing Framework*, 2003.

[1] As of January 2013, a copy of the 2006 report is available at http://www.mvr.usace.army.mil/Missions/EnvironmentalProtectionandRestoration/UpperMississippiRiverRestoration/AboutUs/KeyDocuments.aspx

[2] Authorizing language from the Water Resources Development Act is included in Appendix 1-A.

The goals of this document were to:

- ensure that UMRR-EMP habitat projects address Upper Mississippi River System (UMRS) ecological needs at pool, reach, and system scales by building on existing HREP prioritization mechanisms and integrating the Habitat Needs Assessment Technical Report [3]and other planning efforts into project evaluation;
- enhance public understanding and trust in the decision-making process by making HREP evaluation criteria explicit and consistent; and
- retain the flexibility necessary to ensure efficient, effective program execution and to apply adaptive management principles to project planning, design and implementation.

In 2009, the U.S. Army Corps of Engineers' *Upper Mississippi River System Ecosystem Restoration Objectives*, 2009 was completed as the final product of a planning process initiated in 2008 for the purpose of identifying areas for new restoration projects and identifying knowledge gaps at a system scale. The 2009 Report serves as a technical basis for investment decisions through 2013. The Report serves as a backdrop for the formulation of specific restoration projects and their adaptive ecosystem management components.

C. HREP PROJECT SPECIFIC DOCUMENTATION

Each HREP Project should have associated with it:

- a Fact Sheet
- a Definite Project Report and Environmental Assessment (feasibility level document)
- Plans and Specifications
- Construction Contract(s)
- As-built Construction Drawing(s)
- an Operation and Maintenance Manual
- Performance Evaluation Report(s)

This documentation serves well to follow the history of a project and to compare those items planned, designed and constructed to the final results observed as a result of the construction of these projects.

Most documents associated with HREP projects, and many documents regarding the UMRR-EMP, can be found on the UMRR-EMP website[4].

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[3] Theiling, Korschgen, DeHaan, Fox, Rohweder, Robinson, *Habitat Needs Assessment for the Upper Mississippi River System: Technical Report*, October 2000
[4] As of January 2013, the website is located at http://www.mvr.usace.army.mil/Missions/Environmental Protectionand Restoration/UpperMississippiRiver Restoration.aspx

D. UMRR-EMP HREP DATABASE

A database for HREP projects was developed in the 1990s, and revised in the 2000s. Additional updates such as an interactive mapping and conversion to an Oracle platform are being developed and expected to be implemented by 2013. The purpose of the database is to compile important information at each HREP site and allow the information to be shared and used for future projects. Output tables for the database can range from project specific fact sheets to program analysis of various feature impacts. The database is integrated with GIS data to allow for various query options. It is anticipated that the database, used in coordination with this handbook, will allow for more thorough and streamlined planning of future HREPs. The information in the database is available by contacting the UMRR-EMP Program Manager.

E. UMRR-EMP ENVIRONMENTAL DESIGN HANDBOOK FORMAT

It was determined that a Handbook should be created to describe project features common in HREPs. The UMRR-EMP program covers several rivers and extends through three Corps Districts (St. Paul, Rock Island, and St. Louis), which requires site specific attention be paid to new projects. However, there are numerous similarities in the design of these project features such that the design process can be summarized in this document. Design methodology, case studies, lessons learned, and references are included in each chapter, although the format of these chapters varies based on content. The chapters in the 2012 Handbook are as follows:

Chapter 1 Upper Mississippi River Restoration Environmental Management Program
Chapter 2 Habitat Rehabilitation and Enhancement Projects
Chapter 3 Ecosystem Restoration Objectives
Chapter 4 Shoreline and Riverbank Protection
Chapter 5 Localized Water Level Management
Chapter 6 Dredging
Chapter 7 River Training Structures and Secondary Channel Modifications
Chapter 8 Floodplain Restoration
Chapter 9 Island Design

F. UMRR-EMP ENVIRONMENTAL DESIGN HANDBOOK PREPARATION

This document addresses techniques that are either currently being used on the UMRS or are proposed for future projects. The Handbook addresses the physical characteristics of the process and the habitat objectives.

Work on the 2006 Handbook was initiated in 2004. A team was created, and the Handbook format was discussed in great detail during and UMRR-EMP HREP Design Meeting in January 2005, held at the U.S. Army Corps of Engineers, Rock Island District office. The recommended format was presented to the UMRR EMP Coordinating Committee (UMRR EMP-CC) during their quarterly meetings. The UMRR EMP-CC approved the final format. Primary authors were identified for each chapter and draft chapters were prepared by May 2005. The chapters were distributed to each district for review and to include their own district's information. All information was incorporated and an official draft report was completed in July 2005. In August 2005, the document was discussed at the UMRR-EMP Workshop, held in Davenport, IA. Comments were received during this workshop. An invitation for comments was sent out to the UMRR EMP-CC, service agencies, Corps employees, and others interested in the document. Comments were due by January 2006; however, due to emergency deployments by several individuals in response to Hurricane Katrina, and the War in Iraq, the comment period was extended to May 2006. The comments were incorporated by the primary authors, and the final chapters were completed in July 2006.

Work on the 2012 Handbook was initiated in December 2011. Again, primary authors were identified for each chapter and draft chapters were prepared by May 2012. The chapters were distributed to the UMRR EMP-CC for their review. All information was incorporated and an official draft report was completed in July 2012. In August 2012, a second internal review was completed for the report. The comment response period was extended to allow for emergency deployments or support in response to Hurricane Ivan. The comments were incorporated by the primary authors, and the final chapters were completed in October 2012.

INTRODUCTION

APPENDIX A
ENVIRONMENTAL MANAGEMENT PROGRAM AUTHORIZATION

APPENDIX A
ENVIRONMENTAL MANAGEMENT PROGRAM AUTHORIZATION

Section 1103 of the Water Resources Development Act (WRDA) of 1986 (P.L. 99-662) as amended by
Section 405 of the WRDA of 1990 (P.L. 101-640),
Section 107 of the WRDA of 1992 (P.L. 102-580),
Section 509 of the WRDA of 1999 (P.L. 106-53),
Section 2 of the Water Resources Development Technical Corrections of 1999 (P.L. 106-109), and
Section 3177 of the WRDA of 2007 (P.L. 110-114).

Additional Cost Sharing Provision

Section 906(e) of the WRDA of 1986 (P.L. 99-662) as amended by Section 221 of the WRDA of 1999 (P.L. 106-53).

SEC. 1103. UPPER MISSISSIPPI RIVER PLAN

(a)(1) This section may be cited as the "Upper Mississippi River Management Act of 1986".
(2) To ensure the coordinated development and enhancement of the Upper Mississippi River system, it is hereby declared to be the intent of Congress to recognize that system as a nationally significant ecosystem and a nationally significant commercial navigation system. Congress further recognizes that the system provides a diversity of opportunities and experiences. The system shall be administered and regulated in recognition of its several purposes.

(b) For purposes of this section --
(1) the terms "Upper Mississippi River system" and "system" mean those river reaches having commercial navigation channels on the Mississippi River main stem north of Cairo, Illinois; the Minnesota River, Minnesota; Black River, Wisconsin; Saint Croix River, Minnesota and Wisconsin; Illinois River and Waterway, Illinois; and Kaskaskia River, Illinois;
(2) the term "Master Plan" means the comprehensive master plan for the management of the Upper Mississippi River system, dated January 1, 1982, prepared by the Upper Mississippi River Basin Commission and submitted to Congress pursuant to Public Law 95-502;
(3) the term "GREAT I, GREAT II, and GRRM studies" means the studies entitled "GREAT Environmental Action Team--GREAT I--A Study of the Upper Mississippi River", dated September 1980, "GREAT River Environmental Action Team--GREAT II--A Study of the Upper Mississippi River", dated December 1980, and "GREAT River Resource Management Study", dated September 1982; and
(4) the term "Upper Mississippi River Basin Association" means an association of the States of Illinois, Iowa, Minnesota, Missouri, and Wisconsin, formed for the purposes of cooperative effort and united assistance in the comprehensive planning for the use, protection, growth, and development of the Upper Mississippi River System.

(c)(1) Congress hereby approves the Master Plan as a guide for future water policy on the Upper Mississippi River system. Such approval shall not constitute authorization of any recommendation contained in the Master Plan.
(2) Section 101 of Public Law 95-502 is amended by striking out the last two sentences of subsection (b), striking out subsection (i), striking out the final sentence of subsection (j), and redesignating subsection "(j)" as subsection "(i)".

(d)(1) The consent of the Congress is hereby given to the States of Illinois, Iowa, Minnesota, Missouri, and Wisconsin, or any two or more of such States, to enter into negotiations for agreements, not in conflict with any law of the United States, for cooperative effort and mutual assistance in the comprehensive planning for the use, protection, growth, and development of the Upper Mississippi River system, and to establish such agencies, joint or otherwise, or designate an existing multi-State entity, as they may deem desirable for making effective such agreements. To the extent required by Article I, section 10 of the Constitution, such agreements shall become final only after ratification by an Act of Congress.

(2) The Secretary is authorized to enter into cooperative agreements with the Upper Mississippi River Basin Association or any other agency established under paragraph (1) of this subsection to promote and facilitate active State government participation in the river system management, development, and protection.

(3) For the purpose of ensuring the coordinated planning and implementation of programs authorized in subsections (e) and (h)(2) of this section, the Secretary shall enter into an interagency agreement with the Secretary of the Interior to provide for the direct participation of, and transfer of funds to, the Fish and Wildlife Service and any other agency or bureau of the Department of the Interior for the planning, design, implementation, and evaluation of such programs.

(4) The Upper Mississippi River Basin Association or any other agency established under paragraph (1) of this subsection is hereby designated by Congress as the caretaker of the master plan. Any changes to the master plan recommended by the Secretary shall be submitted to such association or agency for review. Such association or agency may make such comments with respect to such recommendations and offer other recommended changes to the master plan as such association or agency deems appropriate and shall transmit such comments and other recommended changes to the Secretary. The Secretary shall transmit such recommendations along with the comments and other recommended changes of such association or agency to the Congress for approval within 90 days of the receipt of such comments or recommended changes.

(e) Program Authority

(1) Authority

(A) In general. The Secretary, in consultation with the Secretary of the Interior and the States of Illinois, Iowa, Minnesota, Missouri, and Wisconsin, may undertake, as identified in the master plan

(i) a program for the planning, construction, and evaluation of measures for fish and wildlife habitat rehabilitation and enhancement; and

(ii) implementation of a long-term resource monitoring, computerized data inventory and analysis, and applied research program, including research on water quality issues affecting the Mississippi River (including elevated nutrient levels) and the development of remediation strategies.

(B) Advisory committee. In carrying out subparagraph (A)(i), the Secretary shall establish an independent technical advisory committee to review projects, monitoring plans, and habitat and natural resource needs assessments.

(2) REPORTS. — Not later than December 31, 2004, and not later than December 31 of every sixth year thereafter, the Secretary, in consultation with the Secretary of the Interior and the States of Illinois, Iowa, Minnesota, Missouri, and Wisconsin, shall submit to Congress a report that —

(A) contains an evaluation of the UMRR-EMPs described in paragraph (1);

(B) describes the accomplishments of each of the UMRR-EMPs;

(C) provides updates of a systemic habitat needs assessment; and

(D) identifies any needed adjustments in the authorization of the UMRR-EMPs.

(3) For purposes of carrying out paragraph (1)(A)(i) of this subsection, there is authorized to be appropriated to the Secretary $22,750,000 for fiscal year 1999 and each fiscal year thereafter.

(4) For purposes of carrying out paragraph (1)(A)(ii) of this subsection, there is authorized to be appropriated to the Secretary $10,420,000 for fiscal year 1999 and each fiscal year thereafter.

(5) Authorization of appropriations.—There is authorized to be appropriated to carry out paragraph (1)(B) $350,000 for each of fiscal years 1999 through 2009.

(6) Transfer of amounts.—For fiscal year 1999 and each fiscal year thereafter, the Secretary, in

consultation with the Secretary of the Interior and the States of Illinois, Iowa, Minnesota, Missouri, and Wisconsin, may transfer not to exceed 20 percent of the amounts appropriated to carry out clause (i) or (ii) of paragraph (1)(A) to the amounts appropriated to carry out the other of those clauses.
(7)(A) Notwithstanding the provisions of subsection (a)(2) of this section, the costs of each project carried out pursuant to paragraph (1)(A)(i) of this subsection shall be allocated between the Secretary and the appropriate non-Federal sponsor in accordance with the provisions of section 906(e) of this Act; except that the costs of operation and maintenance of projects located on Federal lands or lands owned or operated by a State or local government shall be borne by the Federal, State, or local agency that is responsible for management activities for fish and wildlife on such lands and, in the case of any project requiring non-Federal cost sharing, the non-Federal share of the cost of the project shall be 35 percent.
(B) Notwithstanding the provisions of subsection (a)(2) of this section, the cost of implementing the activities authorized by paragraph (1)(A)(ii) of this subsection shall be allocated in accordance with the provisions of section 906 of this Act, as if such activity was required to mitigate losses to fish and wildlife.
(8) None of the funds appropriated pursuant to any authorization contained in this subsection shall be considered to be chargeable to navigation.

(f) (1) The Secretary, in consultation with any agency established under subsection (d)(1) of this section, is authorized to implement a program of recreational projects for the system substantially in accordance with the recommendations of the GREAT I, GREAT II, and GRRM studies and the master plan reports. In addition, the Secretary, in consultation with any such agency, shall, at Federal expense, conduct an assessment of the economic benefits generated by recreational activities in the system. The cost of each such project shall be allocated between the Secretary and the appropriate non-Federal sponsor in accordance with title I of this Act.
(2) For purposes of carrying out the UMRR-EMP of recreational projects authorized in paragraph (1) of this subsection, there is authorized to be appropriated to the Secretary not to exceed $500,000 per fiscal year for each of the first 15 fiscal years beginning after the effective date of this section.

(g) The Secretary shall, in his budget request, identify those measures developed by the Secretary, in consultation with the Secretary of Transportation and any agency established under subsection (d)(1) of this section, to be undertaken to increase the capacity of specific locks throughout the system by employing nonstructural measures and making minor structural improvements.

(h)(1) The Secretary, in consultation with any agency established under subsection (d)(1) of this section, shall monitor traffic movements on the system for the purpose of verifying lock capacity, updating traffic projections, and refining the economic evaluation so as to verify the need for future capacity expansion of the system.
(2) Determination.
(A) In general. The Secretary in consultation with the Secretary of the Interior and the States of Illinois, Iowa, Minnesota, Missouri, and Wisconsin, shall determine the need for river rehabilitation and environmental enhancement and protection based on the condition of the environment, project developments, and projected environmental impacts from implementing any proposals resulting from recommendations made under subsection (g) and paragraph (1) of this subsection.
(B) Requirements. The Secretary shall
(i) complete the ongoing habitat needs assessment conducted under this paragraph not later than September 30, 2000; and
(ii) include in each report under subsection (e)(2) the most recent habitat needs assessment conducted under this paragraph.
(3) There is authorized to be appropriated to the Secretary such sums as may be necessary to carry out this subsection.

(i) (1) The Secretary shall, as he determines feasible, dispose of dredged material from the system pursuant to the recommendations of the GREAT I, GREAT II, and GRRM studies.

(2) The Secretary shall establish and request appropriate Federal funding for a program to facilitate productive uses of dredged material. The Secretary shall work with the States which have, within their boundaries, any part of the system to identify potential users of dredged material.

(j) The Secretary is authorized to provide for the engineering, design, and construction of a second lock at locks and dam 26, Mississippi River, Alton, Illinois and Missouri, at a total cost of $220,000,000, with a first Federal cost of $220,000,000. Such second lock shall be constructed at or in the vicinity of the location of the replacement lock authorized by section 102 of Public Law 95-502. Section 102 of this Act shall apply to the project authorized by this subsection.

SEC. 906(e). COST SHARING

(e) In those cases when the Secretary, as part of any report to Congress, recommends activities to enhance fish and wildlife resources, the first costs of such enhancement shall be a Federal cost when--

(1) such enhancement provides benefits that are determined to be national, including benefits to species that are identified by the National Marine Fisheries Service as of national economic importance, species that are subject to treaties or international convention to which the United States is a party, and anadromous fish;

(2) such enhancement is designed to benefit species that have been listed as threatened or endangered by the Secretary of the Interior under the terms of the Endangered Species Act, as amended (16 U.S.C. 1531, et seq.), or

(3) such activities are located on lands managed as a national wildlife refuge.

When benefits of enhancement do not qualify under the preceding sentence, 25 percent of such first costs of enhancement shall be provided by non-Federal interests under a schedule of reimbursement determined by the Secretary. Not more than 80 percent of the non-Federal share of such first costs may be satisfied through in-kind contributions, including facilities, supplies, and services that are necessary to carry out the enhancement project. The non-Federal share of operation, maintenance, and rehabilitation of activities to enhance fish and wildlife resources shall be 25 percent.

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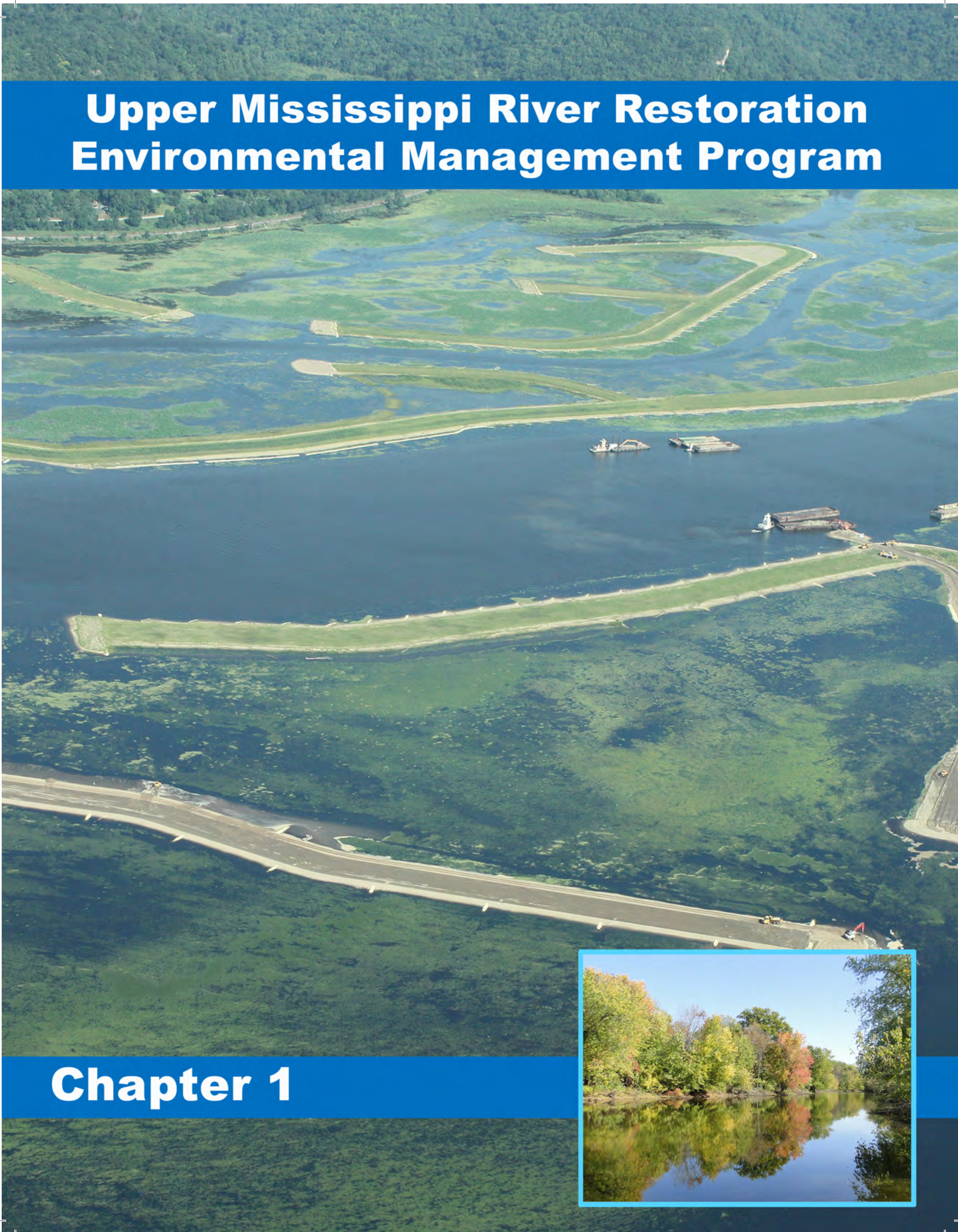

Chapter 1

UPPER MISSISSIPPI RIVER RESTORATION ENVIRONMENTAL MANAGEMENT PROGRAM ENVIRONMENTAL DESIGN HANDBOOK

CHAPTER 1

UPPER MISSISSIPPI RIVER RESTORATION ENVIRONMENTAL MANAGEMENT PROGRAM

Source: http://www.mvr.usace.army.mil/Brochures/MeetingTheChallenge.asp

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CHAPTER 1

UPPER MISSISSIPPI RIVER RESTORATION ENVIRONMENTAL MANAGEMENT PROGRAM

CHAPTER 1

UPPER MISSISSIPPI RIVER RESTORATION ENVIRONMENTAL MANAGEMENT PROGRAM

A. DEVELOPMENT

Ecosystem Restoration is one of the primary missions of the Corps' Civil Works program. The purpose of ecosystem restoration activities is to restore significant ecosystem function, structure, and dynamic processes that have been degraded. Initial congressional authorization of the UMRR-EMPP established a program which allowed for the planning, construction and evaluation of measures for fish and wildlife habitat rehabilitation and enhancement.

Ecosystem restoration efforts involve a comprehensive examination of the problems contributing to the system degradation, and the development of alternative means for their solution. The intent of restoration is to partially or fully reestablish the attributes of a naturalistic, functioning, and self-regulating system (Engineering Circular 1165). In order to understand how to restore the Upper Mississippi River System (UMRS), it is important to understand the changes that have been made to this system for hundreds of years.

Written documentation regarding the Mississippi River tends to coordinate with when European explorers first "discovered" the area, although Native Americans knew of the Mississippi River and inhabited its banks and surrounding areas well before European discovery. Several authors have pulled together information regarding exploration of this time. Some of the prominent explorers included Alonso Álvarez de Pineda, Hernando de Soto, René-Robert Cavelier, Sieur de La Salle, Father Jacques Marquette (or Pere Marqette), a French Jesuit missionary, and Joliet. Documentations from these explorations help to paint a picture of the pre-European settlement river. Lee Sandlin provides an image of the river before the first Europeans arrived:

> *The Upper Mississippi River Valley was always a wild and unknown country. Above St. Anthony Falls in Minnesota, the track of the river meandered into vagueness: it wound through pristine forests, and vanished into unexplored valleys, and glinted among mazes of unnamed lakes. The river's ultimate source wasn't established as Lake Itasca in the far north until the 1830s, and the identification wasn't universally accepted for several decades after that – few people were willing to venture up-country to investigate. The pine forests there were trackless and spooky. The valleys were still strewn with monstrous fossils that had lain undisturbed for thousands of years: mammoths and saber-toothed tigers, dire wolves and a species of beaver that was the size of a grizzle bear – relics from the dawn world of the American wilderness, before the first humans arrived.*
>
> *The current was a fast jog, nine or ten miles an hour in the deepest channels… The Mississippi had no waterfalls south of Minnesota, and only one stretch of dangerous white water, along the Iowa-Illinois border (it was successfully dredged by midcentury). ...There were countless islets and bluffs, feeder creeks and sloughs, marshes and cranebrakes receding into the blue depths of the valley; tributaries came rushing in through ravines; clouds skimmed so low they clipped the pines atop the ridges; drifts of mist floated off the hillsides and melted across the water. Whole*

> *days could go by without the voyaguers seeing anyone onshore...The landscape…was extraordinarily pristine. The most basic traces of human occupation were only sketchily drawn in the valley. There were no main roads or highways; there were barely any trails. There were no long fences or hedgerows marking out property lines. The countryside hadn't yet been pierced and plotted into an array of carpet scraps, the way it is now; forest and meadow and swamp and prairie still flowed into each other according to their own logic. The air was uncannily clear.*

By the 1800s, the Mississippi River was often used for the transportation of goods, but traveling upstream was difficult. The first steamboats entered the southern portion of the river in 1811. The first documented steamboat which traveled into the Upper Mississippi River was the "Western Engineer," a Corps vessel which was able to travel to Keokuk, IA in 1819. At this point, there were two hazardous rapids systems, one in Keokuk and one in Rock Island, which made steamboat traffic in the Upper Mississippi River difficult in low water. Mark Twain discussed the river during this time period in his book "Life on the Mississippi".

> *In the space of one hundred and seventy-six years the Lower Mississippi has shortened itself two hundred and forty-two miles. That is an average of a trifle over one mile and a third per year. Therefore, any calm person, who is not blind or idiotic, can see that in the Old Oolitic Silurian Period, just a million years ago next November, the Lower Mississippi River was upwards of one million three hundred thousand miles long, and stuck out over the Gulf of Mexico like a fishing-rod. And by the same token any person can see that seven hundred and forty-two years from now the Lower Mississippi will be only a mile and three-quarters long, and Cairo and New Orleans will have joined their streets together, and be plodding comfortably along under a single mayor and a mutual board of aldermen. There is something fascinating about science. One gets such wholesale returns of conjecture out of such a trifling investment of fact.*

B. LEGISLATION

Some of the first major modifications made by the Federal government to the Mississippi River began in the 1800s to improve river navigation. Some of the more important milestones follow:

- 1824: The Rivers and Harbors Act of 1824 appropriated funds to remove sandbars, snags and other obstacles in the Mississippi River and was administered by the U.S. Army Corps of Engineers.
- 1824: The General Survey Act of 1824 authorized the president to have surveys made of
- Routes for roads and canals "of national importance, in a commercial or military point of view, or necessary for the transportation of public mail." This was assigned responsibility to the Corps.
- 1829: The Corps recommended that the Rock Island Rapids be improved by widening and straightening the channel.
- 1878: Congress authorized a 4 ½ foot low water channel from St. Louis, MO to St. Paul, MN. This depth was to be achieved primarily by a series of wing and closing dams which would narrow, and thus deepen, the navigation channel.

- 1879: The Mississippi River Commission was created to undertake flood control planning on the lower Mississippi.

By the early 1900s, the tremendous log and lumber rafting industry was nearing its end as the white pine forests of Wisconsin and Minnesota were depleted. Barges were more frequently used to transport goods, but these navigation systems needed more depth than the current 4 ½ foot channel. John Barry, in his book "Rising Tide", noted:

> *To control the Mississippi River – not simply to find a modus vivendi with it, but to control it, to dictate to it, to make it conform – is a mighty task. It requires more than confidence; it requires hubris. It was the perfect task for the nineteenth century. This was the century of iron and steel, certainty and progress, and the belief that physical laws as solid and rigid as iron and steel governed nature, possibly even man's nature, and that man had only to discover these laws to truly rule the world. It was the century of Euclidean geometry, linear logic, magnificent accomplishments, and brilliant mechanics. It was the century of the engineer.*

By 1907, in the Rivers and Harbor Act Congress authorized a 6-foot channel from St. Louis, MO to St. Paul, MN. The 6-foot channel involved dredging, 2,000 new wing dams, and two new locks.

Following several major floods (1912, 1913, and 1927) Congress passed several pieces of legislation to further control the river. President Theodore Roosevelt, who established the Inland Waterways Commission at the time of the 6 foot channel, stated, "*It is not possible to properly frame so large a plan as this for the control of our rivers without taking account of the orderly development of other natural resource.*"

- 1927 River and Harbor Act authorized a Board of Engineers to survey the Mississippi between St. Louis, MO and Minneapolis, MN for a possible 9-foot channel.
- 1928: Flood Control Act of 1928 (70th United States Congress, Sess. 1. Ch. 596, enacted May 15, 1928) authorized the U.S. Army Corps of Engineers to design and construct projects for the control of floods on the Mississippi River and its tributaries.
- 1930: the Rivers and Harbor Act of July 3, 1930, authorized the nine foot channel and appropriated funds and provided for a uniform lock size of 110 by 600 feet.
- 1936: The Flood Control Act of 1936, Pub.L. 74-738, (FCA 1936) was an Act of the United States Congress signed into law by President Franklin Delano Roosevelt on 22 June 1936:

  The Flood Control Act of 1936 established an enormous commitment by the federal government to protect people and property on approximately 100 million acres [400,000 km²]. The only limitations on federal flood control projects were that the economic benefits had to exceed the costs, and local interests had to meet the ABC requirements for local projects. Since 1936, Congress has authorized the Corps of Engineers to construct hundreds of miles of levees, flood walls, and channel improvements and approximately 375 major reservoirs. These remarkable engineering projects today comprise one of the largest single additions to the nation's physical plant -rivaled only by the highway system. They have saved billions of dollars in property damage and protected hundreds of thousands of people from anxiety, injury, and death. They stand today as one of the more significant marks of our technical skill and humane spirit.

By the 1970s, the Federal government was passing many environmental laws and regulations. As outlined in Rachel Carson's book, "Silent Spring":

> *The history of life on earth has been a history of interaction between living things and their surroundings. To a large extent, the physical form and habits of the earth's vegetation and animal life have been molded by the environment. Considering the whole span of earthly time, the opposite effect, in which life actually modifies its surroundings, as been relatively slight. Only within the moment of time represented by the present century has one species – man – acquired significant power to alter the nature of our world.*

In the 1970s, a proposal to replace Lock and Dam 26 near Alton, IL, and increase its navigation capacity, sparked considerable debate and litigation regarding its environmental impacts. As outlined by John Madson:

> *You will hear it called "The Great Sewer," the intestinal tract of America's midsection, fit only for commercial traffic and waste disposal. There is something to that, but the larger truth is that great stretches of the Mississippi are lovely corridors of wildness that still honor the original landscapes in what otherwise is a blank monotony of corn, soybeans and cotton. It is a pity that we have profaned and strictured parts of the River, spoiling so much of it for ourselves, but from the River's point of view that is all transitory. Even the great channel dams are only petty, fleeting little restraints. A few miles from where I am writing this, the crumbling Lock and Dam 26 is being replaced by a vast new edifice costing hundreds of millions and which, in the next half-tick of the Mississippi's ancient clock, will, in turn, crumble. No dam can survive such a river's displeasure indefinitely, and it is not the River's pleasure to be blocked and bound. In spite of our contempt for the integrity of great rivers, the Mississippi will shrug off our abuse and move on.*

In 1978, Congress authorized construction of a new dam with a single, 1,200-foot lock and directed the Upper Mississippi River Basin Commission to conduct studies and make recommendations related to further navigation capacity expansion and its ecological impacts.

The Commission presented its findings and recommendations in a landmark document, the Upper Mississippi River Basin Commission, *Comprehensive Master Plan for the Management of the Upper Mississippi River System*, in January 1982. The Master Plan recommended that Congress authorize: a second lock, 600 feet in length, at Lock and Dam 26; a habitat rehabilitation and enhancement program; a long term resource monitoring program; a computerized inventory and analysis system; recreation projects; and a study of the economic impacts of recreation. In addition, the Commission proposed actions to reduce erosion rates, increase the capacity of other locks through non-structural and minor structural measures, monitor traffic movements, continue dredged material placement practices, promote beneficial uses of dredged material, and coordinate State water resources management activities.

The Comprehensive Plan provided an outline for what is today referred to as the UMRR-EMP. Prior to passage of the 1986 WRDA, Congress used the 1985 Supplemental Appropriations Act (Public Law 99-88) to initiate a number of water projects by directing that the Corps of Engineers proceed with construction and providing the funds necessary to do so. Among the 41 projects advanced in this way was environmental management along the Upper Mississippi River Basin. The conference committee report accompanying the 1985 supplemental appropriations measure also set forth the basic framework for the UMRR-EMP. In the absence of more elaborate statutory provisions, the conferees directed that funds equal to those provided for advanced engineering and design of the second lock be used for initial activities related to programs for long term resource monitoring, habitat rehabilitation and enhancement, recreation improvements and studies, traffic monitoring, and computerized inventory and analysis.

C. AUTHORIZATION FOR THE UMRR-EMP

The 1986, the WRDA (Public Law 99-662), Section 1103 authorized both construction of a second lock at Locks and Dam 26 and a variety of environmental initiatives on the Upper Mississippi River. This section was entitled the Upper Mississippi River Management Act of 1986. It is the statutory basis for the UMRR-EMP, though the law does not confer that name upon the UMRR-EMP. The effect of using this national legislation, the first program in the Nation to combine ecosystem restoration with scientific monitoring and research efforts on a large river system, as a vehicle to authorize the Upper Mississippi River programs was twofold: first, the authority for implementing all the Upper Mississippi River program elements was vested in the Corps; secondly, cost-sharing for UMRR-EMP habitat projects was mandated.

The UMRR-EMP has served the Nation for over 25 years on the UMRS. As of April 2012, the UMRR-EMP has received and applied a total of $422,925,000 which has supported broad ranging efforts to restore aquatic habitats, acquire systemic data, and monitor and research the UMRS. These efforts have improved the quality of aquatic habitat and associated floodplain habitats, benefiting fish, waterfowl, shorebirds, mammals, amphibians, reptiles, neo-tropical migrant birds, and many species of plants. In addition to providing important benefits on the UMRS, the UMRR-EMP serves as a model for other aquatic ecosystem efforts nationally and internationally and remains viable and relevant. It 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 commercial navigation system.

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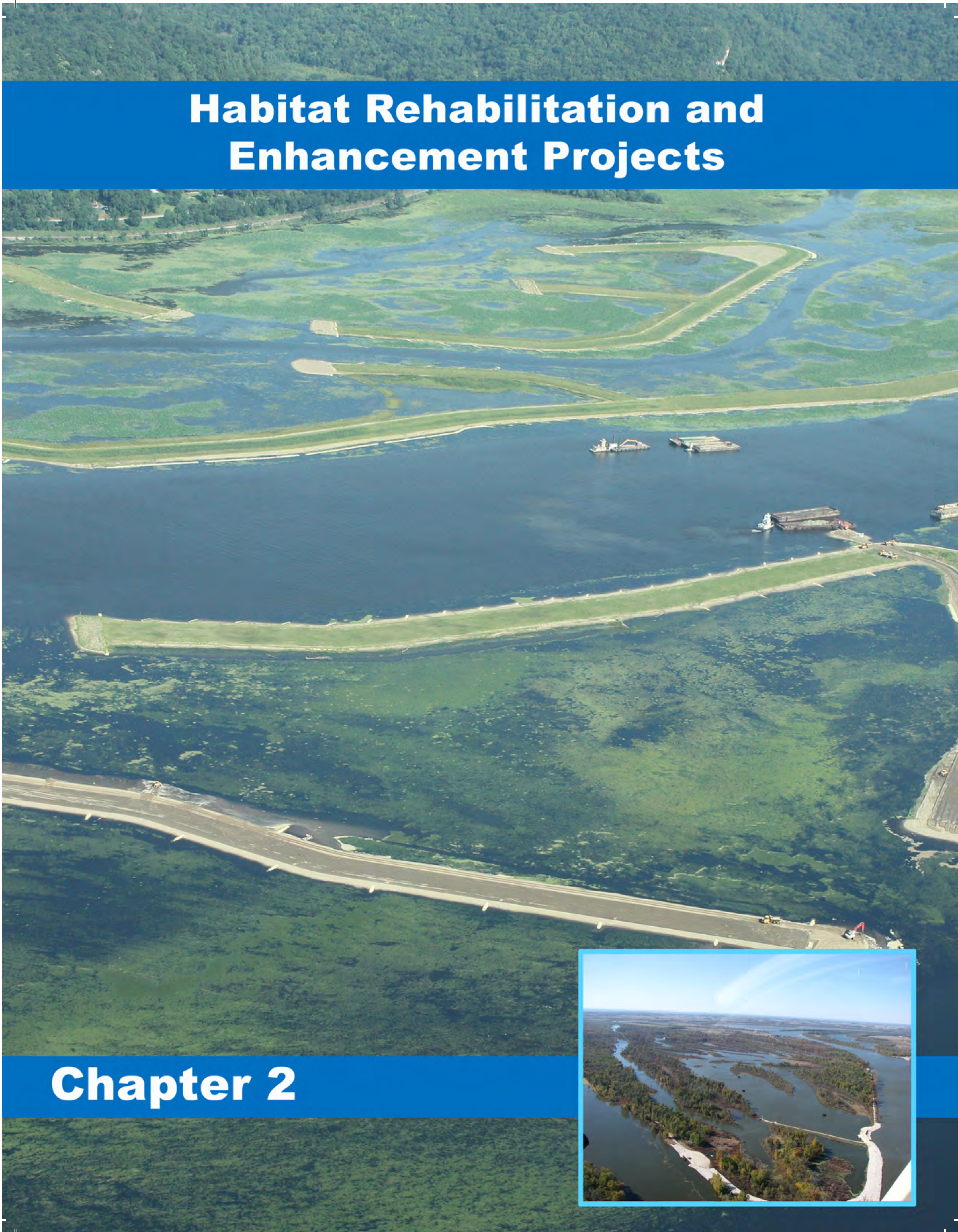
Habitat Rehabilitation and Enhancement Projects

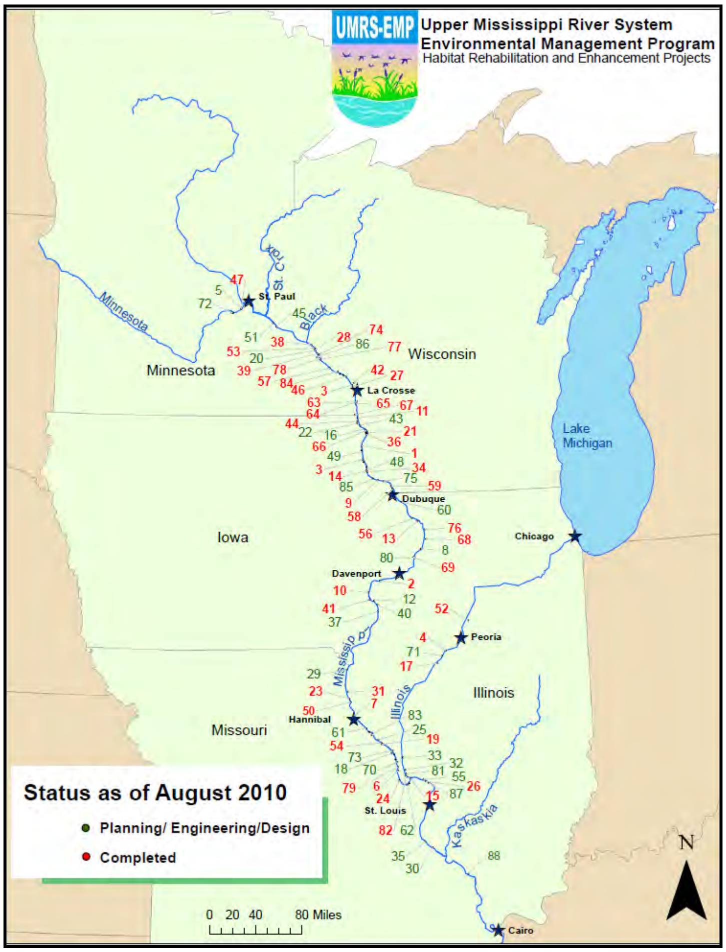


Chapter 2

UPPER MISSISSIPPI RIVER RESTORATION ENVIRONMENTAL MANAGEMENT PROGRAM ENVIRONMENTAL DESIGN HANDBOOK

CHAPTER 2

HABITAT REHABILITATION AND ENHANCEMENT PROJECTS



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CHAPTER 2

HABITAT REHABILITATION AND ENHANCEMENT PROJECTS

FIGURE

TABLES

CHAPTER 2

HABITAT REHABILITATION AND ENHANCEMENT PROJECTS

A. INTRODUCTION

The UMRR-EMP restoration planning approach and techniques have served both nationally and internationally as models for other river restoration planners. Habitat Rehabilitation and Enhancement Projects (HREPs) modify the river's floodplain structure and hydrology to counteract the factors that are degrading habitat. For example, HREPs may alter sediment transport and deposition, water levels, or the connections between the river and its floodplain. These types of physical changes subsequently affect water quality parameters such as temperature, dissolved oxygen, and distribution of suspended sediments, thereby ultimately improving fish and wildlife habitat.

When UMRR-EMP began, HREP designers implemented and refined construction techniques to improve habitats in ways not previously imagined. The intent was to improve habitat through site specific modifications. HREPs successfully combined a broad range of construction techniques with approaches that strive to use or mimic natural riverine processes, providing benefits to the river at system, reach, pool, and local scales. HREPs continually build upon lessons learned in constructing and managing prior projects, as well as UMRR-EMP's foundational partner coordination and implementation mechanisms.

As of 2012, the UMRR-EMP has received and applied a total of $285,671,000 for its ecosystem restoration efforts, known as HREPs, since its 1986 authorization. The HREP locations are shown in Figure 2-1. This funding has allowed for completion of 54 projects (table 2-1), benefiting approximately 100,000 acres of UMRS habitat at an average approximate cost of $2,900 per acre. An additional 36 HREPs are currently under development or in construction (table 2-2).

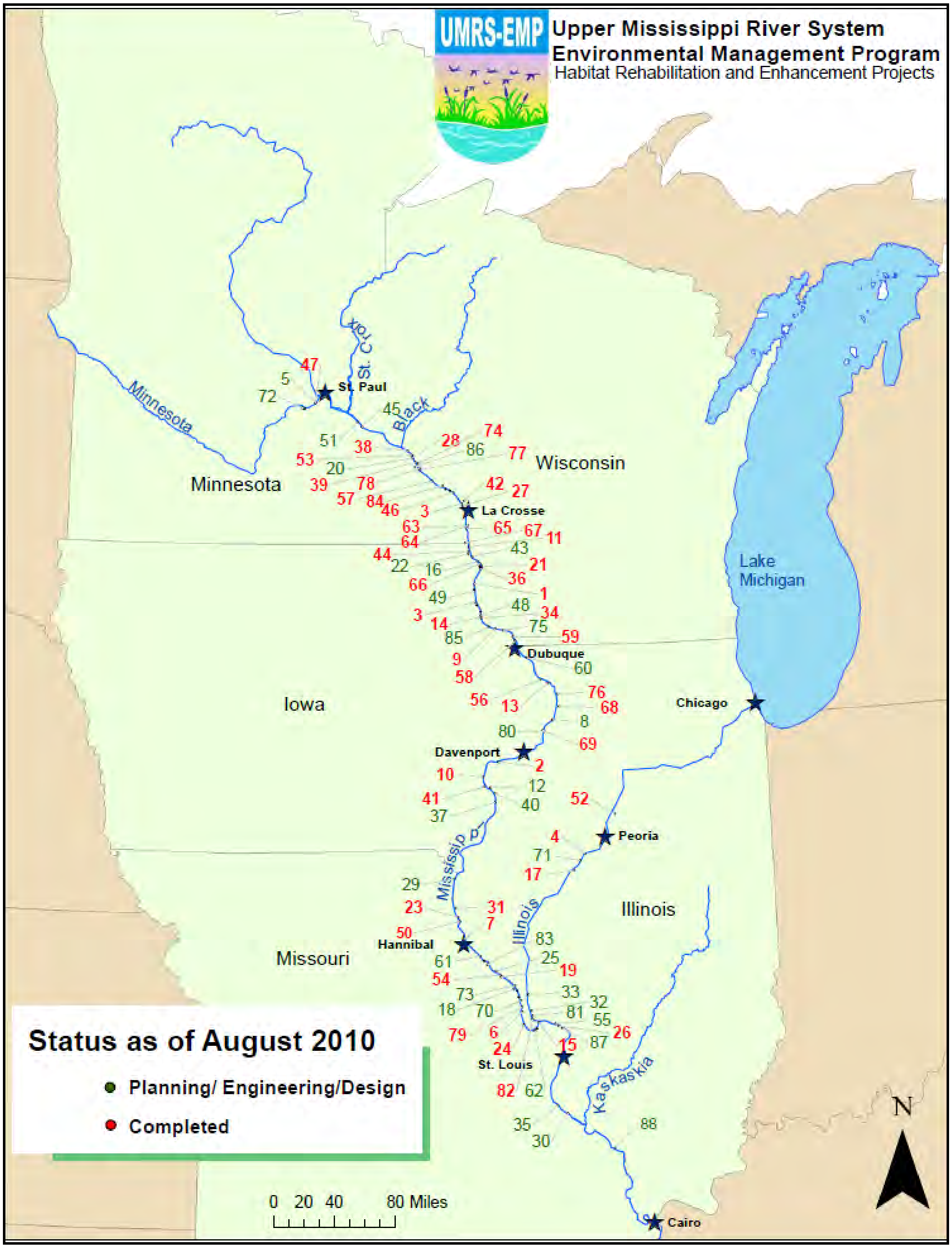


Figure 2-2. Habitat Rehabilitation and Enhancement Projects[1]

[1] Numbers in Figure 2-1 relate to the site reference numbers in Table 2-1.

Table 2-1. HREP Project Listing

EMP HREP Projects	Site Ref.	EMP HREP Projects	Site Ref.
Ambrough Slough	1	Long Meadow Lake	47
Andalusia Refuge	2	Lower Pool 10 Island and Backwater Complex	48
Bank Stabilization	3	McGregor Lake	49
Banner Marsh	4	Monkey Chute	50
Bass Ponds, Marsh, and Wetlands	5	North and Sturgeon Lakes	51
Batchtown Management Area	6	Peoria Lake	52
Bay Island	7	Peterson Lake	53
Beaver Island Complex	8	Pharrs Island	54
Bertom & McCartney Lakes	9	Piasa/Eagle's Nest Islands	55
Big Timber	10	Pleasant Creek	56
Blackhawk Park	11	Polander Lake	57
Boston Bay	12	Pool 11 Islands-Sunfish Lake	58
Brown's Lake	13	Pool 11 Islands-Mud Lake	59
Bussey Lake	14	Pool 12 Overwintering	60
Calhoun Point	15	Pool 24 Islands	61
Capoli Slough	16	Pool 25 & 26 Islands	62
Chautauqua Refuge	17	Pool 8 Islands - Phase I	63
Clarence Cannon	18	Pool 8 Islands - Phase II	64
Clarksville Refuge	19	Pool 8 Islands - Phase III	65
Clear Lake	20	Pool 9 Islands	66
Cold Springs	21	Pool Slough	67
Conway Lake	22	Potters Marsh	68
Cottonwood Island	23	Princeton Refuge	69
Cuivre Island	24	Reds Landing	70
Delair Division	25	Rice Lake-IL	71
Dresser Island	26	Rice Lake-MN	72
East Channel	27	Rip Rap Landing	73
Finger Lakes	28	Small Scale Drawdown	74
Fox Island Habitat Rehab & Enhancement Project	29	Snyder Slough Backwater Complex	75
Ft Chartres Side Channel	30	Spring Lake	76
Gardner Division	31	Spring Lake Islands	77
Glades Wetland Complex	32	Spring Lake Peninsula	78
Godar Refuge Wetland	33	Stag and Keeton Islands	79
Guttenberg Waterfowl	34	Steamboat Island	80
Harlow Island	35	Stump Lake	81
Harpers Slough	36	Swan Lake	82
Huron Island	37	Ted Shanks Conservation	83
Indian Slough	38	Trempealeau Refuge	84
Island 42	39	Turkey River Bottoms Delta and Backwater Complex	85
Keithsburg Division	40	Weaver Bottoms	86
Lake Odessa	41	West Alton Tract	87
Lake Onalaska	42	Wilkinson Island	88
Lake Winneshiek	43		
Lansing Big Lake	44		
Lock & Dam 3	45		
Long Lake	46		

Table 2-2. UMRR-EMP HREP Completed Projects (F), as of April 2012, by District
St. Paul (MVP), Rock Island (MVR), or St. Louis (MVS)

Project Name	Corps District	Status	Percent Complete [1]	Acres Affected	Backwater Dredging	Water Level Mgmt	Islands	Bank Stabilization	Side Channel Restoration	Aeration	Other [2]
Ambrough Slough, WI	MVP	F	100	2,920	X			X	X	X	
Blackhawk Park, WI	MVP	F	100	150					X	X	
Bussey Lake, IA	MVP	F	100	1,680	X	X	X			X	
Clear Lake (Finger Lake) Dredging, MN	MVP	F	100	20	X						
Cold Springs, WI	MVP	F	100	30	X					X	
East Channel, WI, MN	MVP	F	100	320				X			
Finger Lakes, MN	MVP	F	100	530		X				X	X
Guttenberg Waterfowl Ponds, IA	MVP	F	100	80	X	X					
Indian Slough, WI	MVP	F	100	1000	X			X	X		X
Island 42, MN	MVP	F	100	420	X				X	X	
Lake Onalaska, WI	MVP	F	100	2,750	X		X	X		X	
Lansing Big Lake, IA	MVP	F	100	6,420					X	X	
Long Lake, WI	MVP	F	100	40				X		X	
Long Meadow Lake, MN	MVP	F	100	2,340		X					X
Mississippi Bank Stabilization, IA, MN, WI	MVP	F	100	1,300				X			
Peterson Lake, MN	MVP	F	100	990			X	X	X		
Polander Lake, MN	MVP	F	100	790	X		X	X			
Pool 8 Islands Phase I, WI	MVP	F	100	1000	X		X	X			
Pool 8 Islands Phase II,WI	MVP	F	100	600	X		X	X			X
Pool 8 Islands Phase III, WI	MVP	F	100	3,320	X		X	X	X		X
Pool 9 Islands, WI	MVP	F	100	410			X				
Pool Slough, IA, MN	MVP	F	100	620		X					
Rice Lake - MN	MVP	F	100	810	X	X					X
Small Scale Drawdown, WI	MVP	F	100	90		X					X
Spring Lake Islands, WI	MVP	F	100	520	X		X	X	X	X	X
Spring Lake Peninsula, WI	MVP	F	100	30	X		X	X	X		
Trempeleau, WI	MVP	F	100	5,900		X		X			

Project Name	Corps District	Status	Percent Complete [1]	Acres Affected	Backwater Dredging	Water Level Mgmt	Islands	Bank Stabilization	Side Channel Restoration	Aeration	Other [2]
Andalusia Refuge, IL	MVR	F	100	320	X	X	X			X	
Banner Marsh, IL	MVR	F	100	4,290		X					X
Bay Island, MO	MVR	F	100	750		X					X
Bertom McCartney Lakes, WI	MVR	F	100	2,340	X		X	X	X		X
Big Timber, IA	MVR	F	100	1,240	X						X
Brown's Lake, IA	MVR	F	100	1,120	X					X	X
Chautauqua Refuge, IL	MVR	F	100	3,940		X					
Cottonwood Island, MO	MVR	F	100	990	X						X
Lake Odessa, IA	MVR	F	99[3]	6,320	X	X		X	X		X
Gardner (Long Island) Division, IL	MVR	F	100	6,090	X			X			X
Monkey Chute, MO	MVR	F	100	110	X						
Peoria Lake, IL	MVR	F	100	2,500		X	X				X
Pleasant Creek, IA	MVR	F	100	680		X					
Pool 11 Islands-Mud Lake, IL, WI	MVR	F	100	4,550	X		X	X	X	X	X
Pool 11 Islands-Sunfish Lake, IL, WI	MVR	F	100	4,000	X		X	X	X	X	X
Potters Marsh, IL	MVR	F	100	1,200	X	X				X	X
Princeton Refuge, IA	MVR	F	100	1,080		X					X
Spring Lake, IL	MVR	F	100	3,610		X					X
Batchtown, IL	MVS	F	99[3]	3,280		X					X
Calhoun Point, IL	MVS	F	99[3]	2,140	X	X					
Clarksville Refuge, MO	MVS	F	100	310		X					
Cuivre Island, MO	MVS	F	100	2,180		X			X		X
Dresser Island, MO	MVS	F	100	1,030	X	X					
Pharrs Island, MO	MVS	F	100	670							X
Stag and Keaton Islands, MO	MVS	F	100	470					X		
Stump Lake, IL	MVS	F	100	3,170		X					
Swan Lake, IL	MVS	F	99[3]	4,920	X	X					
Completed Projects (54)				**98,380**							

[1] Includes planning, design, construction and close-out.
[2] This category includes floodplain and tributary restoration and other newer and complementary restoration techniques.
[3] Projects do not require additional construction funding to complete.

Table 2-3. Status of UMRR-EMP HREPs in Design (D)[1] and Construction (C), as of April 2012 by District St. Paul (MVP), Rock Island (MVR), or St. Louis (MVS) and Percent of Project Completed

Project Name	Corps District	Status	Percent Complete	Acres Affected	Backwater Dredging	Water Level Mgmt	Islands	Bank Stabilization	Side Channel Restoration	Aeration	Other
Capoli Slough, WI	MVP	C	35	820	X		X	X	X		X
Clear Lake Area Habitat Restoration, MN	MVP	D	1	185	X		X				
Lock & Dam 3 Fish Passage, WI	MVP	D	15	660							X
Lake Winneshiek, WI	MVP	D	8	5,170	X		X	X	X		X
Harpers Slough, IA, WI	MVP	D	10	1,880	X		X	X	X		
Conway Lake, IA	MVP	D	2	1,110	X	X	X	X	X	X	X
Bass Ponds, Marsh, and Wetland, MN	MVP	D	1	390	X	X			X		X
Lower Pool 10 Is. Backwater Complex, IA	MVP	D	1	2,000	X		X				X
McGregor, WI	MVP	D	1	1,000	X		X				X
North and Sturgeon Lakes, MN	MVP	D	1	4,600	X	X	X				X
Weaver Bottoms, MN	MVP	D	1	4,880	X		X				X
Fox Island, MO	MVR	C	60	2,030		X					X
Rice Lake-IL	MVR	C	50	6,350		X					X
Pool 12 Overwintering, IA, IL	MVR	D	25	7,990	X						X
Huron Island, IA	MVR	D	18	2,670	X	X					X
Beaver Island, IA	MVR	D	3	1,750	X					X	X
Boston Bay, IL	MVR	D	1	900	X	X				X	X
Delair Division, IL	MVR	D	1	2,080		X				X	X
Keithsburg Division, IL	MVR	D	1	1,390		X			X		X
Snyder Slough Backwater Complex, WI	MVR	D	1	4,280	X		X				X
Steamboat Island, IA	MVR	D	1	1,280	X		X				X
Turkey R. Bottoms Delta and Backwater, IA, WI	MVR	D	1	3,150	X	X		X			X
Pool 25 and 26 Islands, MO	MVS	C	35	4,020	X		X	X			
Ted Shanks, MO	MVS	C	15	3,330		X					X
Ft Chartres Side Channel, MO	MVS	D	7	60					X		
Rip Rap Landing, IL	MVS	D	6	1,810		X			X		
Clarence Cannon, MO	MVS	D	5	3,590		X			X		X
Glades Wetland Complex, IL	MVS	D	1	320	X	X					X

Project Name	Corps District	Status	Percent Complete	Acres Affected	Backwater Dredging	Water Level Mgmt	Islands	Bank Stabilization	Side Channel Restoration	Aeration	Other
Godar Refuge, IL	MVS	D	1	250		X			X		X
Harlow Island, MO	MVS	D	1	1,300					X		X
Piasa And Eagles Nest Islands, IL	MVS	D	1	390	X		X		X		X
Pool 24 Islands, MO	MVS	D	1	3,150	X					X	X
Red's Landing Wetlands, IL	MVS	D	1	1,620		X			X	X	X
Schenimann, MO	MVS	D	15	705	X				X		
West Alton Tract, MO	MVS	D	1	610	X		X		X		X
Wilkinson Island, IL	MVS	D	5	700	X		X		X		X
PROJECTS UNDER CONSTRUCTION (5)				**16,550**							
PROJECTS IN DESIGN (31)				**61,870**							
TOTAL (36)				**78,420**							

[1] In UMRR-EMP, projects are considered in design from when a project fact sheet is approved until approval of the Definite Project Report (DPR),which incorporates both reconnaissance and feasibility level planning with periodic review and approval by the Major Subordinate Command. Construction includes the deveoplment of plans and specifications.

B. HREP FEATURE COMPONENTS

To accomplish their habitat management and restoration objectives, HREPs employ a variety of techniques including: island creation, shoreline protection, water level management, backwater dredging, river training structures, secondary channel modification, aeration, floodplain restoration, and tributary restoration. Many projects combine these features to address more complex problems. The range of techniques that have been used, or are being considered for possible future use, is extensive (table 2-4.) These techniques are described in more detail in subsequent chapters.

Table 2-4. EMP HREP Features

Category	Actions	Features
Channel and Backwater Restoration	Islands	Barrier Islands
		Seed Islands
		Log Rock Structures
		Mud Flats
		Turtle Nesting Mounds
		Sand Flats
		Delta Formation
	Water Level Management	Pool Scale Drawdowns
		Backwater Scale Drawdowns
		Gate Operation Improvement
		Winter operation at top of band
	Dredging	Backwater dredge cuts
		Secondary Channel dredge cuts
	Channel Restoration	Partial/Complete Rock Closures
		Rock liners
		Dredging
		Wing dam/Closing Dam Mods.
	Island/Shoreline Stabilization	Groins, Vanes, Woody Structure
		Seed Islands
	Aeration channels/structures	Gated culverts
	Embankment Modifications	Rock Ramps
		Gated Culverts
		Spillway Notches
		Near-Shore Berms
	Topographic Diversity	Dredge Material Placement
	Regulation	Mooring Buoys
		No-wake zones
Floodplain Restoration	Land Protection	Fee title/easements
	Connectivity Restoration	Dike/Levee Breach
	Distributary Channel Restoration	Dike/Levee Breach
		In-stream Structures
	Moist Soil Management	Pump Stations
		Dike/Levee Construction
	Floodplain Vegetation Restoration	Reforestation, Planting Native Shrubs and Forbs
		Control of invasive species
		Forest Stand Improvement
	Topographic Diversity	Dredge material placement
	Native Floodplain Management	Prescribed Burns
		Control of invasive species

C. HREP IDENTIFICATION AND PRIORITIZATION

Based on information contained in the 1997 Report to Congress, habitat projects were initially nominated for inclusion in the EMP by the respective State natural resource agencies and/or the USFWS based on agency management objectives; documented habitat needs; professional judgment; funding availability; and, at times, social considerations. With this information, projects being considered reflected broader regional needs in addition to representing the best site-specific choices. Priority projects are then recommended to the Corps district for initiation of planning activities.

In 2003, an HREP Planning and Sequencing Framework was completed to describe the proposed four-stage HREP planning and sequencing process. This process builds upon the existing HREP selection process to create a more systemic, comprehensive approach that is transparent and accessible to project partners and stakeholders. The ecological merits of proposed projects remain the most important factor in determining HREP priorities. Other factors to be considered include project-specific administrative issues and consistency with overall program goals. The process includes the development of a fact sheet, then proceeding with four steps: a district ecological evaluation, a system ecologic evaluation, program planning, and Corps management decisions. Detailed descriptions of this process are included in the 2003 HREP Planning and Sequencing Framework document located on the UMRR-EMP web site.

The 2003 HREP Planning and Sequencing Framework is a systemic, comprehensive planning approach that is transparent and accessible to project partners and stakeholders. This approach facilitates selection of projects that address UMRS ecological needs at the local, reach, and system scales. In 2006-2007, UMRR-EMP used this Framework to identify new projects, which are now all either under MVD's review or in the initial design stage.

D. HREP PLANNING GUIDANCE DOCUMENTS

There are numerous planning policies that are used for developing projects, and the information provided below serves to highlight some of these processes, but should not replace these official documents. Ensure that each project has a team leader that is aware of the current requirements throughout the planning and design process.

- The 1997 Report to Congress provides a detailed description of the planning, engineering and design for HREP projects.
- U.S. Army Corps of Engineers, ER 1105-2-100, *Planning - Planning Guidance Notebook*, April 2000. ER 1105-2-100 states that numerous Federal laws and executive orders establish National policy for and Federal interest in the protection, restoration, conservation and management of environmental resources. These provisions include compliance requirements and emphasize protecting environmental quality. Recent water resources authorizations have enhanced opportunities for Corps involvement in studies and projects to specifically address objectives related to the restoration of ecological resources and ecosystem management. Specific authorities for new individual studies and projects to restore ecological resources have also been provided in legislation. Examples of legislation that broadly supports Federal involvement in the restoration and protection of ecological resources include: Federal Water Project Recreation Act of 1965, as amended; Water Resource Development Acts of 1986,

1988, 1990, 1992, 1996 and 1999; and Coastal Wetlands Planning, Protection and Restoration Act of 1990 (Title III of P.L. 101-646)

- The Corps ecosystem restoration policy is described in more detail in ER 1165-2-501, Civil *Works Ecosystem Restoration Policy*, 30 September 1999
- EP 1165-2-502, *Water Resources Policies and Authorities - Ecosystem Restoration - Supporting Policy Information*, 30 September 1999 policy applies to all ecosystem studies and projects
- Planning Community Toolbox is a web site maintained by the U.S. Army Corps of Engineers Headquarters which provides a list of Chief's Reports, Guidance Memos and Planning ECs, Ems, EPs, ERs, EGMs, and PGLs as well as WRDA and Related Laws. As of May 2012, the link to this site was as follows: http://planning.usace.army.mil/toolbox/library.cfm?Option=Start
- In 2010, a meeting was held between the Corps offices in MVD, MVR, MVS and MVP to discuss the programmatic review process for UMRR-EMP HREP. A copy of the memo documenting the meeting, which describes the appropriate steps for the review process, is available from the UMRR-EMP Program Manager.

E. THE DEFINITE PROJECT REPORT

The UMRR-EMP HREP process conducts and integrated environmental assessment and a feasibility study in the Definite Project Report (DPR). While the report formats have varied over the life of the UMRR-EMP HREP to address changes in Corps planning process, the general criteria included in the DPR are as follows:

1. Introduction
2. Assessment of Existing Resources
3. Project Objectives
4. Potential Project Features
5. Evaluation of Feasible Project Features and Formulation of Alternatives
6. Recommended Plan
7. Schedule for Design and Construction
8. Cost Estimates
9. Environmental Effects
10. Project Performance Assessment Monitoring
11. Real Estate Requirements
12. Implementation Responsibilities and Views
13. Coordination, Public Views, and Comments
14. Conclusions

Appendices to the DPR often include some or all of the following:

A. Correspondence
B. Memorandum of Agreement or Cooperation Agreement
C. Cost
D. Design Calculations
E. Water Quality
F. Clean Water Act Compliance

G. Geotechnical Considerations
H. Hydrology and Hydraulics
I. Hazardous, Toxic and Radioactive Waste
J. Structural
K. Mechanical
L. Electrical
M. Baseline Biological Monitoring
N. Habitat Evaluation and Quantification
O. Plan Formulation
P. Monitoring and Adaptive Management
Q. Value Engineering
R. Real Estate Plan
S. Literature Cited
T. Distribution List
U. Plates

F. EXISTING RESOURCES, GOALS, OBJECTIVES, AND POTENTIAL PROJECT FEATURES

When funds are received for detailed planning and design on a proposed project, a multidisciplinary team of Corps planners, engineers, scientists, and technicians is assembled to initiate detailed project planning. This team works closely with an interagency team of biologists and natural resource managers to identify site-specific resource problems, constraints, and project goals and objectives.

Coincident with the formulation of goals and objectives is the identification of potential project features. For early HREPs, pre-project monitoring data was often limited, and performance data for similar projects was not available for comparison or refinement of design parameters; so the interagency project team worked together to develop project designs using the following general criteria to identify and assess alternative project features:

- Locate and construct features consistent with UMRR-EMP directives and guidance and best planning and design practices

- Construct features consistent with Federal, State and local laws

- Establish goals and objectives that can be monitored

G. PRELIMINARY DESIGN

As interagency teams planned individual projects, HREP design was further refined based on the following factors:

- project goals and objectives
- hydraulic, geotechnical, structural engineering factors
- economics (habitat benefits versus project costs)
- constructability
- aesthetics
- acceptable level of risk and uncertainty

While these criteria and factors continue to be used, project design has evolved because of lessons learned on earlier projects, input from researchers, and evolving natural resource management philosophies. In addition, mathematical and analytical modeling of flow, wind effects, and sediment transport has advanced since the program's beginnings and is used extensively in project design. Essentially, HREP engineering and design developed as the program developed, resulting in enhanced habitat benefits and reductions in most project implementation costs.

HREP construction, monitoring results, and improved technological tools have all contributed to advances in HREP design. Through the use of GIS and 2-dimensional numerical hydrodynamic models, the outcome resulting from construction of certain HREP features can be more reliably predicted. For example, two dimensional hydrodynamic models have been used to refine the layout of islands. Design standards have been adjusted to promote innovation and reduce project costs. Project successes have become the basis for development of design standards for various types of HREPs.

H. EVALUATION OF FEASIBLE PROJECT FEATURES AND FORMULATION OF ALTERNATIVES

For project planning purposes, formulation of alternatives is accomplished through habitat assessment and Incremental Cost Analysis (ICA). Habitat assessment uses ecological models to provide a numerical score (e.g., model output) to the current habitat condition and to the predicted future habitat condition with and without enhancement features. The difference between the numerical score with the enhancement feature and score without the feature is the feature's habitat benefit. The outputs of the ecological models are use in an incremental cost analysis to evaluate what enhancement features, individually or in combination, are most cost-effective. Costs for each feature, including construction, operation, maintenance, and monitoring are annualized and input into the ICA. Alternative development is basically a four-step procedure:

1. calculate the habitat benefit for each feature;
2. estimate the cost of each feature;
3. evaluate the cost/benefit ratio of each feature, and
4. determine the best buy project alternative based on habitat benefits, cost, and achievement of project goals and objectives.

I. PLANNING MODELS & HABITAT ASSESSMENT

The Corps' Planning Models Improvement Program (PMIP) was established in 2003 to assess the state of planning models in the Corps and to make recommendations to assure that high quality methods and tools are available to enable informed decisions on investments in the Nation's water resources infrastructure and natural environment. The main objective of the PMIP is to carry out "a process to review, improve and validate analytical tools and models for U.S. Army Corps of Engineers Civil Works business programs." The PMIP Task Force collected the views of Corps leaders and recognized technical experts, and conducted investigations and numerous discussions and debates on issues related to planning models. It identified an array of model-related problems, conducted a survey of planning models, prepared papers on model-related issues, analyzed numerous options for addressing these issues, formulated recommendations, and wrote a final report that is the basis for the development of EC 1105-2-412*, Assuring Quality of Planning Models, 31 March 2010*.

Planning models are defined as any combination of models and analytical tools that planners use to define water resources management problems and opportunities, to formulate potential alternatives to address the problems and take advantage of the opportunities, to evaluate potential effects of alternatives and to support decision-making. It includes all models used for planning, regardless of their scope or source. This does not cover engineering models used in planning activities. Guidance on quality assurance for engineering models is contained in ER 1110-2- 1150, *Engineering and Design for Civil Works Projects*.

Planning models are either certified or approved. A certified model is one which has been reviewed and certified by the appropriate Planning Center of Expertise (PCX) and Headquarters (HQ). Models will be considered for approval (rather than certification) if they have been developed by an entity outside the Corps. Models will also be considered for approval in cases where a model has been developed by the Corps and is viewed by the vertical team (including the District, MSC, PCX, and HQ) as single-use or study-specific (which will include many ecosystem output models).

Habitat evaluation procedures use ecological models to assess existing and future without-project conditions in the study area, and to evaluate the anticipated habitat outputs of features or alternatives. Recent guidance, EC 1105-2-412, *Assuring Quality of Planning Models, 31 March 2010,* requires that models used to evaluate enhancement features be certified. The Corps' Ecosystem Restoration PCX Model Library [2] serves ecosystem restoration planners and practitioners by consolidating and providing access to information about ecosystem restoration planning models and software. The website provides a list of certified ecosystem models and guidance for model certifications and reviews. The library provides information about each model's scope and geographic range of applicability, documentation availability, points of contact, and review status relative to U.S. Army Corps of Engineers requirements for model quality assurance review. Engineering Circular 1105-2-412, *Assuring Quality of Planning Models, 31 March 2010* provides guidance on model certifications, as does the HQ Memorandum, *Policy Guidance on Certification of Ecosystem Output Models*, August 2007. Model certification guidance can also be found in the Corps' National PCX document *Assuring Quality of Planning Models – Model Certification/Approval Process, Standard Operating Procedures, February 2012.*

J. INCREMENTAL COST ANALYSIS

An ecosystem restoration proposal must be justified on the basis of its contribution to restoring the structure and function, or both, of a degraded ecosystem, when considering the cost of the proposal. Ecosystem restoration projects are justified through a determination that the combined monetary and non-monetary benefits of the project are greater than its monetary and non-monetary costs. An ICA is a planning tool rooted in economic production theory and utilizes such economic principles as scarcity, choice and opportunity cost. The cost analysis examines changes in cost and output that result from decisions to implement alternatives and alternative components. An ICA can be used to identify the least-cost alternative for producing every attainable level of environmental output, as well

[2] As of May 2012, this information was available at the following web site: http://cw-environment.usace.army.mil/model-library.cfm?CoP=Restore&Option=Start

as identifying those alternatives where more output could be produced for the same or less cost. Environmental scale selection choices based on average, instead of incremental cost information, can lead to misinformed and improper decision-making. The rationale behind ICA is to *reveal* the variation in cost between one alternative and another, whereas average cost tends to *obscure* the variation in cost between alternatives. An ICA is an invaluable tool in determining the appropriate scale of mitigation or restoration by revealing variations in cost between alternative; explicitly asking for each attainable increment of output, "Is it worth it?"

The information used in formulating, evaluating and selecting ecosystem restoration features/alternatives includes both quantitative and qualitative information about outputs, costs, significance, acceptability, completeness, effectiveness, and reasonableness of costs. This information is summarized in EP 1165-2-502, *Ecosystem Restoration - Supporting Policy Information*, 1999 and guidance on developing this information and descriptions of the four evaluation criteria (acceptability, completeness, effectiveness, and efficiency) are provided in ER 1105-2-100, *Planning Guidance Notebook*, 2000.

An ecosystem restoration plan should represent a cost effective means of addressing the restoration problem or opportunity. It should be determined that a plan's restoration outputs cannot be produced more cost effectively by another alternative plan. Cost effectiveness analysis is performed to identify least cost plans for producing alternative levels of environmental outputs expressed in non-monetary terms. Incremental cost analysis identifies changes in costs for increasing levels of environmental output. It is used to help assess whether it is worthwhile to incur additional costs in order to gain increased environmental outputs.

K. NATIONAL ECOSYSTEM RESTORATION (NER) PLAN

Engineering Regulation 1105-2-100 directs that Corps of Engineers ecosystem restoration projects should contribute to national ecosystem restoration. The NER plan reasonably maximizes ecosystem restoration benefits compared to costs, considering the cost effectiveness and incremental cost of implementing other restoration options. The NER plan must be identified within the DPR, and may or may not be the same as the recommended plan.

L. TENTATIVELY SELECTED PLAN/RECOMMENDED PLAN

The PDT will select a tentatively selected plan (TSP). Once the TSP goes through various levels of review and is approved by the Mississippi Valley Division, it will become the recommended plan. A recommended ecosystem restoration plan must make a justified contribution to addressing the specified ecosystem restoration objectives. Information regarding resource significance and the significance of expected restoration outputs is used in conjunction with information from cost effectiveness and incremental cost analyses to help determine whether an alternative is justified. Discussions concerning significance should address the following:

- relevant recognition of the environmental resources in terms of institutional, public, and technical importance,
- effects on the resources in terms of differences between estimated future without- and with plan conditions, and,

- other relevant information concerning duration, frequency, location, magnitude, and other characteristics, such as reversibility, irretrievability, and the relationships to short-term uses and long-term productivity

Following completion of these analyses, the interagency team selects the combination of enhancement features that best serves the needs of the resource, while being cost effective. Also, less conservative, experimental designs are considered and, if feasible, incorporated into project design. Project design involves individuals from State and Federal agencies, as well as nongovernmental organizations and the general public. The results of the analyses and investigations described above are documented in a Definite Project Report (DPR) prepared by the Corps with input from the States and the USFWS. T he DPR also evaluates the TSP for potential impacts to the human environment in accordance with applicable State and Federal environmental laws and regulations. Real estate requirements are identified, operation and maintenance requirements are evaluated, and a detailed project cost estimate is developed. The DPR is coordinated with the other involved Federal and State agencies and resource interests, and made available for general public review. The DPR is forwarded to the Corps' higher authority with a recommendation for project implementation approval.

M. PROJECT COOPERATION AGREEMENTS

UMRR-EMP habitat projects are either 100 percent federally funded or require a non-Federal sponsor to pay 35 percent of the project cost. Which of these options applies is governed by Section 906(e) of the 1986 WRDA. Section 906(e) authorizes 100 percent Federal funding for projects that (1) are located on lands managed as a national wildlife refuge, (2) benefit federally-threatened or endangered species, or (3) provide benefits that are determined to be national (e.g., benefit anadromous fish or species subject to treaty). All other UMRR-EMP habitat projects require a 35 percent non-Federal cost share.

For habitat projects that require a 35 percent non-Federal cost share, the Corps and the non-Federal project sponsor sign and execute a Project Partner Agreement (PPA) detailing the obligations and responsibilities of both parties. For these projects, the non-Federal sponsor (normally a State natural resource agency but it may also be a Non-Government Organization) assumes the responsibility of the non-Federal sponsor. For projects with a Federal sponsor, a Memorandum of Agreement (MOA) is written and signed.

N. PROJECT DESIGN

After approval of the project, the responsible Corps district prepares detailed project plans and specifications with input from the project sponsor. The plans and specifications refine the recommended plan as presented in the DPR and comply with Corps guidance and regulations and good engineering practices. The Corps works closely with the sponsor and with construction personnel during the development of plans and specifications to ensure that all considerations are adequately addressed. The plans and specifications process follows the standard Corps review process, and when complete are advertised for construction.

O. PROJECT CONSTRUCTION

HREPs have provided new opportunities to test construction techniques and project design in the river floodplain environment. One of the greatest challenges in project construction can be site conditions, as projects are often located in remote areas of the floodplain. To meet this challenge, more recently constructed HREPs have featured contracts with shorter construction seasons to reduce the risk of flooding, utilized materials such as sheet pile to cut dewatering costs, or staged construction to facilitate access to the site. Construction modifications and unforeseen costs of early HREPs emphasized the importance of sound engineering investigations during design, including collection of sufficient geotechnical, hydraulic, and surveying data.

P. OPERATION, MAINTENANCE, REPAIR, REHABILITATION AND REPLACEMENT

HREPs pose a significant operation, maintenance, repair, rehabilitation and replacement (OMRR&R) responsibility for states and the USFWS. As more HREP projects are completed, OMRR&R costs continue to increase. HREPs can be designed to reduce OMRR&R intensity. However, those projects are typically more expensive to construct. Thus, UMRR-EMP should consider 1) the appropriate balance between reducing OMRR&R expenses and construction costs, 2) how to address increasing cumulative OMRR&R responsibilities for the states and the USFWS, and 3) a protocol for documenting OMRR&R costs and activities.

In accordance with Section 107 (b) of the WRDA of 1992, Public Law 102-580, UMRR-EMP cost-sharing provisions were amended to assign sole responsibility for OMRR&R of habitat projects to the agency that manages the lands on which the project is located.

The HREP projects now consist of over 100,000 acres of restored or enhanced habitat that require various levels of OMRR&R. Some HREP project features require more intensive OMRR&R than others, such as those necessary for water level management and sediment reduction. In 2000, the USFWS submitted a letter to the Corps of Engineers identifying short falls in OMRR&R funding within the agency. A similar, if not more pronounced, condition also confronts State partners. The overall effectiveness of the environmental restoration program for the UMRS is largely dependent upon adequate OMRR&R funding for HREPs. The USFWS previously projected that its annual OMRR&R obligation for HREP projects on national wildlife refuge lands will grow to over $740,000 by 2015. The States' respective funding needs are unknown at this time; however, OMRR&R costs are outlined in each HREP's OMRR&R Manual.

Operation and maintenance of UMRR-EMP habitat projects is similar to that undertaken by the partner agencies in day-to-day management of parks, boat ramps, wildlife management areas and other such public use areas. Activities include inspections, debris removal sediment removal, road or access maintenance, seeding, mowing, pumping, water control structure operation, structure maintenance, etc. Occasionally, feature damage or component failure requires investment by the sponsor that was not planned for in sponsor's budget. Particular examples include earthworks, pump motors, and water control structures. The purpose of assigning OMRR&R costs to the federal or nonfederal partner is to ensure commitment and accountability to the EMP by the project sponsor. While the projects are analyzed over 50 years, they are constructed to last into perpetuity or until deauthorized.

Operation, maintenance, repair, rehabilitation and replacement considerations may extend outside of the typical 50 year period of analysis, as the project sponsor is expected to maintain the HREP Project until it is no longer authorized. Items in this area can include electrical systems, gates, trash racks, stoplogs, and concrete structures. Rehabilitation is the reconstructive work that significantly exceeds the annual operation and maintenance requirements and is needed as a result of major storms or flood events.

Funding for OMRR&R comes from both federal dollars budgeted through the Department of the Interior (USFWS) and from state funds through the five UMRS states' (IL, IA, MN, MO, and WI) natural resource agencies. If a sponsor were f another Federal agency or a non-governmental agency, funding would be their responsibility. Prior to 1992, HREP OMRR&R was governed by Section 906(e) of WRDA 86, which required cost-sharing of OMRR&R. This administratively complex approach was simplified in WRDA 92, which assigned 100 percent of OMRR&R responsibility to the agency that manages the project lands. This policy was reinforced during the first Report to Congress in 1997. There were no recommendations in the 1997 Report to Congress that would change the responsibility for HREP projects. However, since the EMP has completed 25 years of construction of HREP projects, the number of projects and associated OMRR&R costs are increasing.

Q. ADAPTIVE MANAGEMENT

The UMRR-EMP is continually enhancing its restoration and monitoring techniques using insights gained from completed projects, systemic and project monitoring, and applied research findings. The UMRR-EMP has an explicit process for incorporating engineering lessons learned through a prescribed planning and design process, operations manuals, project performance inspections, and the Environmental Design Handbook which integrates best practices of the program. However, the program does not have a similar explicit process to learn about ecosystem responses or to link ecosystem responses with engineering techniques. Active adaptive management (AM) offers explicit approaches to learn about biological responses related to ecosystem restoration.

Throughout its history, the UMRR-EMP has implemented ecological monitoring, focused research, and HREP biological response monitoring to gain insights on the UMRS ecosystem and to enhance future restoration efforts.

The UMRR-EMP has been a national leader in ecosystem restoration implementation and the lessons learned on the UMRS and on other large aquatic ecosystems have been incorporated into recent USACE policy updates. The Corps was granted greater authority and responsibility for AM and ecosystem restoration response monitoring under Section 2039 of WRDA 2007. All Corps ecosystem restoration projects will include plans to review project performance and need to consider opportunities for AM. Whereas prior project performance monitoring focused on constructed features, the 2007 authority allows for greater consideration for biological response to be included in project performance evaluation.

UMRR-EMP has and continues to pioneer new ecosystem restoration and biological monitoring techniques for large rivers. Learning has always been a central theme for the program. This has resulted in improved project formulation, engineering, and design and the adoption of new technologies and techniques for monitoring and research, allowing the program to maintain and enhance its efficiency and effectiveness over the past 26 years. Therefore, implementing AM is a natural step as it is part of an ongoing process to improve the program. The anticipated benefits of

AM are to help in prioritizing information needs, establishing review processes, integrating program elements, and increasing communication.

R. PROJECT MONITORING & PERFORMANCE EVALUATION REPORTS

Physical and biological response monitoring of HREPs has added significantly to the wealth of information available on the river. Ongoing monitoring of projects will produce data necessary to develop physical and biological response models for use in refining future project designs.

Pre-project physical and biological monitoring is done to quantify resource problems such as low dissolved oxygen levels, island erosion, and backwater sedimentation. Post-project monitoring allows specific measurement of physical and biological variables affected by projects and provides data for use in future project development.

The physical effects of HREPs on water movement are well understood. While many of the physical and chemical responses to a project (e.g., changes in dissolved oxygen, water temperature, or water velocity) can usually be determined shortly after construction, several years of monitoring may be required to determine certain selected physical and biological responses to the project (e.g., changes in sediment deposition, fish populations, invertebrates, and vegetation composition). The initial response to project construction may be much different than what happens over the life of a project.

Much of the intensive monitoring of biological response to HREPs has been accomplished using HREP funds. The decision to limit biological response monitoring was made early in the program because the individual and cumulative cost of pursuing detailed, quantitative assessments of the biological effects of every HREP constructed would be high and would reduce available funds for HREP design and construction.. Where detailed monitoring has been completed, the results have generally supported management's evaluations of habitat problems.

Because an HREP project provides benefits within a larger surrounding system, the need for and success of the project must be assessed in this broader context. Fish abundance estimates conducted at an HREP site may only indicate how local population change. The actual benefit of the project may lead to population improvements off site that are undetectable by short-term, site-specific sampling. Because of this, the species specific area of influence is important (e.g., fish that can move 8 to 10 miles can utilize more widely dispersed habitat than one limited to a couple of miles). To this end, input from natural resource managers, scientists, and resource users (i.e., anglers, hunters, and other recreationists) is extremely valuable.

Existing Biological Monitoring consists of forestry survey, aquatic macrophytes, aquatic macroinvertebrates, migratory waterfowl, fish, and aquatic vegetation.

Existing physical and chemical monitoring in the 3 districts includes discharge and velocity in project areas, water surface elevations bathymetry/topography, water quality, sediment transects, levee transects/cross sections, aerial photography, LIDAR, land use/land cover, soil borings Site visits and interviews with Resource Managers are also used to assess project conditions

Performance Evaluation Reports (PER) are used to:

1. Document the pre- and post-construction monitoring activities

2. Summarize and evaluate project performance on the basis of project goals and objectives
3. Summarize project operation and maintenance efforts to date
4. Provide recommendations concerning future project performance evaluation
5. Share lessons learned and provide recommendations concerning the planning and design of future HREPs

Table 2.5 provides the status of PERs, as of February 2012, for the completed HREPs within the UMRS.

S. HREP LESSONS LEARNED

There have been many lessons learned during the design, construction, operation, and evaluation of HREP projects. Many of these lessons are included in the following chapters. There are many lessons that should be applied across the entire HREP process, and a list of these have been compiled and are included in table 2.6.

Table 2.5. Completed PER Reports as of February 2012

Project Name	River	Pool	Initial PER Completed	PER Date	PER Date	PER Date	PER Date
Rice Lake	Minnesota		31-May-2012				
Island 42	Mississippi	5	1-Aug-1995				
Blackhawk Park	Mississippi	9	1-Sep-2004				
Guttenberg Ponds	Mississippi	11	1-Dec-2011				
Lake Onalaska	Mississippi	7	1-Sep-2004				
Pool 8 Phase 1 Stage 1 & 2	Mississippi	8	1-Sep-2004				
Bussey Lake Stage 1,1B & 2	Mississippi	10	1-Sep-2004				
Indian Slough Stage 1 & 2	Mississippi	4	1-Dec-2011				
Cold Springs	Mississippi	9	1-Sep-2004				
Peterson Lake	Mississippi	4	1-Dec-2011				
East Channel	Mississippi	8	1-Sep-2004				
Small Scale Drawdown	Mississippi	5 & 9	4-Sep-2012				
Chautauqua	Illinois	LaGrange	(Bio responses)				
Cottonwood	Mississippi	21	1-Jun-2001	1-Apr-2002			
Long Island (Gardner)	Mississippi	21	1-Jul-2003	1-Jun-2004			
Pool 11	Mississippi	11					
Spring Lake	Mississippi	13	2006 water quality report				
Pleasant Creek	Mississippi	13	31-August-2012				
Bay Island	Mississippi	22	1-Dec-1999	1-Apr-2002	1-Mar-2003		
Andalusia	Mississippi	16	1-Aug-1997	1-Jun-2001	1-Apr-2002	1-Jul-2003	
Banner Marsh	Illinois	LaGrange	1-Aug-2002	1-Aug-2002			
Bertom and McCartney	Mississippi	11	1-May-1995	1-May-2002	1-Sep-2003		
Big Timber	Mississippi	17	1-Oct-1995	1-Feb-1996	1-Aug-1998	1-Jun-2001	1-Apr-2002
Brown's Lake	Mississippi	13	1-Feb-1993	1-Sep-1996	1-Apr-1997	1-Oct-2003	
Peoria	Illinois	Peoria	1-Mar-2001	1-May-2002			
Potters Marsh	Mississippi	13	1-Nov-1998	1-Aug-2002	1-Oct-2003		
Princeton	Mississippi	14	1-Nov-2001	1-Sep-2005			
Cuivre Island	Missouri	26	Draft 2007				
Swan Lake	Illinois	26	2010				
Stump Lake	Illinois	26	2012				
Clarksville Refuge	Missouri	24	1996				

Table 2-6. HREP Lesson Learned

Topic	Description	Addressing Phase	Evaluation Phase
Access Dredging	Access Dredging should be limited to locations shown on the drawings. Material from access dredging can be used for placement on island depending on material characteristics as determined by soil samples.	Design	Construction
Access Pads	Pool 8 Islands - Access Pads are a construction feature that limits the amount of access dredging required. They can either be left in or removed depending on stakeholders and Government desires. Typical size is max of 100 x 250 ft.	Design	Construction
As-Built Drawings	Closeout Spec should describe the format and detail to be provided with the As-Built Drawings. Meta Data format is needed for As-Built info. to be useful in doing Long Term Monitoring.	Design	Construction/ Long Term Monitoring
Borrow Sources/ Cost Sharing	Channel Granular Borrow Sources - Use Operations (Channel Maintenance) granular borrow sites where possible and quantify savings and work with Operations on Project Cost Sharing.	Planning	Design
Borrow Sources - Locations	Identify Borrow Sources meeting design requirements that are as close to the work area as reasonably possible. Borings should be done where necessary before solicitation to confirm proposed borrow source has material meeting specifications.	Planning	Construction
Construction Schedules	Limited Work Windows - One of greatest challenges is working through all the limited work windows associated with critter requirements - bats, astors, eagle nests, etc. Work windows are also affected by high water durations as well as seeding and planting restrictions. Carefully planning work -developing project activity schedules during planning & design phase is critical to understanding how best to 'package' and contract the work to minimize cost impacts of these restrictions.	Planning/Design	Construction
Construction Schedules	Agency Work Restrictions - Working with the agencies to forego a hunting season can be a cost & time & accident saver. Many projects are constructed in USFWS "closed areas" significantly shortening the length of constructions seasons.	Planning/Design	Construction

Table 2-6. HREP Lesson Learned

Topic	Description	Addressing Phase	Evaluation Phase
Construction Schedules	Splitting up Projects to Match Available Funding. Too often funding availability (or lack thereof) drives a construction schedule rather than when construction can be realistically completed given all the government imposed restrictions. Splitting Projects into stages can result in duplicate contractor mobilizations, construction inefficiencies, (and design inefficiencies). Good planning in how work is staged can eliminate many of the inefficiencies.	Planning/Design	Construction
Contract Types	LPTA (lowest price technically acceptable) or best value type contracts and evaluations of contractor qualifications can be valuable contracting tools for environmental restoration projects to ensure that the contractor is aware of the environment in which they will be constructing (flooding, droughts, coordination with resource agencies)	Contracting	Construction
Differing Site Conditions	Changes routinely occur in the field during a project. Ensure that the design team is aware of these changes as it may greatly affect how the project functions or additional coordination that will be needed with the sponsor. Regular partner or coordination meetings facilitate communication during construction	Construction	Construction
Emergent Wetlands	Pool 8 Stages 2B and 3A - Emergent wetlands elevations should vary between up to 2ft with the mean elevation .5ft below LCP. Wetlands should not be table smooth and should slope toward the sand berm and away from islands. Sand berms (containment dike) are required for hydraulic placement during construction, but the height is left up to contractor. Contractor work plan as required by specification, should describe construction details.	Design	Long Term Monitoring
Erosion Protection	Erosion Protection is required as soon as possible after granular placement begins. Contractor may want to construct the vanes or groins concurrent with granular placement. All islands must be completed in full section at the end of each construction season.	Design	Construction
Fine Material - Depth	***Low Islands -*** minimum of 9" is required for fine materials (these islands have increased access to moisture). ***Medium or High Islands -*** Minimum of 12' fine materials is required.	Design	Long Term Monitoring

Table 2-6. HREP Lesson Learned

Topic	Description	Addressing Phase	Evaluation Phase
Geotechnical - General	Borings are an issue on many projects. (1) Get input from construction personnel on locations to take borings. (2) When feasible, some borings should obtained after the island features, or borrow sites are identified, ***so the borings are within the footprint of these features.***	Planning/Design	Construction
Geotechnical Considerations	Fox Island - Design of water distribution channels did not account for approximately 50% of the channel excavation being comprised of pure sand which isn't conducive to moving water in the volume and distance required to fill existing ponds. Borings on the channel excavation alignments would have been beneficial.	Design	Construction
Geotechnical Considerations	Fox Island - Borings did not account for ground water elevations at critical excavation levels for new water control structure construction. Borings at the structure sites would have been beneficial.	Design	Construction
Geotechnical Considerations	Fox Island - Test bore holes for new well construction failed to identify large cobble and rocks at approximately the 30' depth at both new well locations approximately 1 mile apart. Cost and time escalation was realized and well installation methods were changed dramatically upon the discovery of the cobble.	Design	Construction
Geotechnical Considerations	Sand lenses are quite typical in HREP areas. If at all possible coordinate with local onsite individuals that can verify if locations typically hold water or tend to dry up quickly once high water recedes.	Planning/Design	Construction
Inlet/Outlet Structures	Inlet and outlet channels have routinely had sedimentation challenges. To the greatest extent possible, locate inlet/outlet structures and pump stations closer to the river rather than further away.	Design	Long Term Monitoring
Inlet/Outlet Structures	Ensure that sufficient riprap/bank stabilization is placed around inlet/outlet structures. The tendency is to keep the stabilization to a minimum when going for the maximum is usually the better approach.	Design	Long Term Monitoring
Levees	Shallower berm/embankment/levee slopes equals less muskrat burrowing damage (Spring Lake).	Design	Long Term Monitoring

Table 2-6. HREP Lesson Learned

Topic	Description	Addressing Phase	Evaluation Phase
Moist Soil Units	HREPs that include moist soil units typically hold water for extended periods of time. To the greatest extent possible provide bank stabilization methods above and below the projected water line.	Design	Long Term Monitoring
Partnering - During Planning, Design, and Contraction	Work to involve sponsors and stakeholders during planning and design phase and keep them engaged during construction through use of "Partner Meetings" . These meeting are typically held every 1 to 2 weeks during active construction. Issues raised at the meetings are either resolved immediately, or an action plan is developed to get resolution to not impact construction schedules.	Planning, Design, and Construction	Construction
Partnering - Training	If working with new Contractor or if there is there is need to improve the Partnering Process either with the Contractor or stakeholders, schedule a formal or facilitated Partnering Session	Construction	Construction
Plantings	Fox Island, Banner Marsh, Gardner - Marry up cover crop, seeding requirements and maintenance of tree planting areas to promote tree maturation and survival.	Design	Construction
Plantings	In MVP contracts, willows have proven to be cost effective for shoreline erosion control. Experience has shown that successful planting is limited to the spring (or no later than 15 June). To save money and to engage stakeholders and the public, additional tree planting has been coordinated by OP-RNR after construction.	Design	Construction
Plantings - Trees	Tree planting on narrow, elevated ridges to increase survival rates tends to hinder growth. Close coordination with foresters on the appropriate height and width of planting areas is required to ensure an increase in tree survivability.	Design	Long Term Monitoring
PPA/MOA	PPAs: Coordinate with HQ personnel to ensure the preferred model PPA is used at the outset, don't rely on regs/guidance. Also check the HQ website for required PPA package items because no review is started until all items are received.	Planning	?

Table 2-6. HREP Lesson Learned

Topic	Description	Addressing Phase	Evaluation Phase
Pump Stations	Ensure that pump tests, pump inspections, float tests, surge protectors, humidity devices, etc. (i.e. everything that has to do with pump stations) are checked, inspected, verified and fully accepted before allowing the contractor to proceed on. We have had more problems with pumps than probably all other items combined.	Contract	Construction
Pump Stations	Ensure that all hatches and grating have a procedure in place to lock them open so that the hatches to do not close unexpectedly causing a safety hazard.	Design	Construction
Pump Stations	Channels constructed to pump stations or inlet structures have high sedimentation rates. To the greatest extent possible, locate inlet/outlet structures and pump stations closer to the river rather than further away. Build these structures as close to the main channel as possible (Brown's Lake has recurring problem).	Design	Long Term Monitoring
Pump Stations	Electrical equipment and pump stations are subject to damage from high water. Ensure that electrical equipment is placed above the 500 year (or higher if possible) flood level.	Design	Long Term Monitoring
Pump Stations	Chautauqua - Maintenance and/or repair of pump station components requires the dewatering of the pump station sump area. Pump station component maintenance and repair should be examined for user friendliness.	Design	Long Term Monitoring
Pump Station	Ventura Marsh – Consider carefully discharge configurations to address pressurization and soil characteristics. Ensure that soil will rebound when the dewatering system for construction is demolished.	Design	Construction
Real Estate Considerations	Fox Island - Temporary and permanent easements are not in place for reasonable contractor - and eventually user - access to one new water control structure. Assure any and all easements are acquired ahead of construction activities.	Permits	Construction

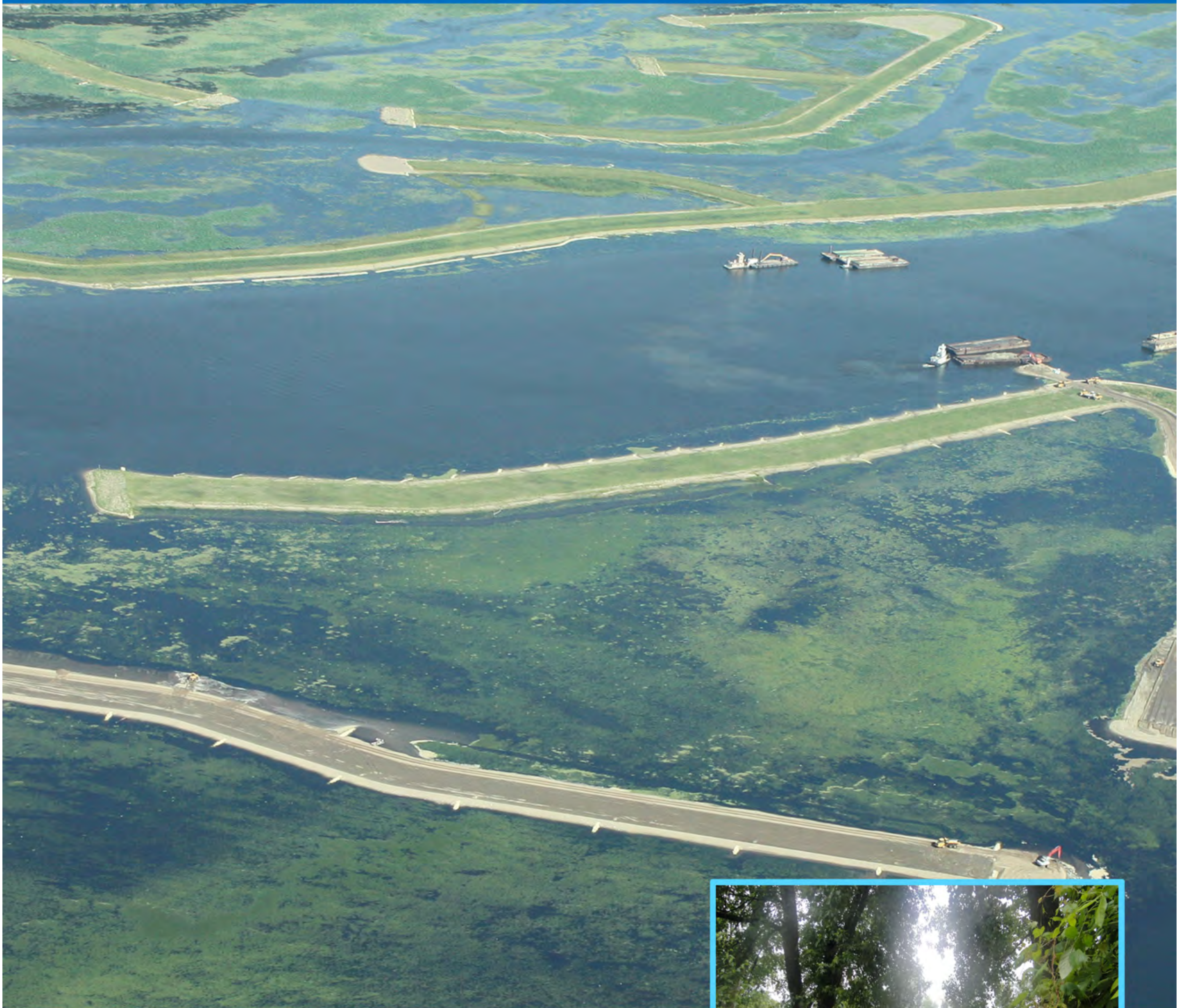
Table 2-6. HREP Lesson Learned

Topic	Description	Addressing Phase	Evaluation Phase
Real Estate/ Construction Access	Chautauqua and Fox Island - If a contract feature of work is going to require excessive access through a small town (Goofy Ridge, IL and Alexandria, MO) do not rely on a contractor to be required to repave existing streets after several thousand tons of materials have been delivered on those streets. If there is only one way in and one way out via public roads for delivery of construction materials and a contractor is in compliance with all load requirements of those access routes - a contractor can't be held accountable for rehabilitation of those streets/haul routes.	Contract	Construction
Seeding	Pool 8 Islands - Seeding: (1) Keep the seed mix simple since the first overtopping changes the seed mix to what is carried by the river. (2) Seeding in spring is preferable, but successful establishment can be achieved for seeding in all but the 15 June to 15 August time period, if moisture conditions are favorable.	Design	Construction
Seeding - Mulching	Pool 8 Islands - Most specifications require mulching of newly seeded areas. Mulching is the best alternative if it will not result in excessive rutting of seeded areas. Successful establishment has been achieved without mulching.	Design	Construction
Survey	Fox Island & Several Other EMP Projects - Reliance on a single or minimal design cross sections (channel & levee) doesn't always fit the actual field conditions encountered during construction. Design should be applicable to all field conditions.	Design	Construction
Survey	Fox Island - Designed water management water levels do not match existing lake bottom and channel conditions. Assure design and future use is based on recent and accurate survey - especially if the site is subject to frequent flooding.	Design	Construction
Survey	Ensure that surveys are checked and rechecked and the contractor checks and rechecks the surveys. We have had many problems with old surveys, incorrect surveys, pieced together surveys, cheap surveys, etc. It has ALWAYS been worth the money to make sure the surveys are right.	Design	Construction

Table 2-6. HREP Lesson Learned

Topic	Description	Addressing Phase	Evaluation Phase
Survey - Deliverables	It is recommended that survey specifications include: (1) a survey plan as a submittal and (2) list of survey and quantity deliverables. At a minimum, deliverables should include: (a).pre-survey with quantities by feature, (b) interim surveys (as necessary) for payment verification and (c) final surveys with cross sections and quantities within neat lines or required tolerances.	Design	Construction
Surveys - General	Pool 8 Stage 3A - Bathymetry Data used for planning and design is sometimes old and does not represent current conditions. Inaccurate data greatly affects project quantities, site access, and can lead to a differing site condition.	Design	Construction
Water Level Management	Chautauqua - Assure the contract specifically addresses ownership or responsibility of any and all water control structure levels from the construction site to any adjoining rivers. At Chautauqua, nobody (Owner/sponsor, USACE or contractor) wanted to take responsibility for gate openings on a water control structure from the ILWW to the upper lake and eventually that indecision was at least in part cause to a complete loss of that existing structure and construction of a new structure.	Planning	Construction
Water Management Plan	Ensure that the contractor has a detailed water management plan and that the Corps has thoroughly reviewed it for both dewatering and for rising high water. We have had two times (Chautauqua and Banner Marsh) where this has caused major problems.	Construction	Construction
Wells	HREPs with wells need to address iron eating bacteria maintenance/concerns so that waterfowl fully use the ponded water areas constructed	Planning	Long Term Monitoring
Work Conditions	HREPs are constructed in typically wet and potentially flooded areas. Insure that the contractors are fully aware of the normal conditions that exist on the site in a "typical" year.	Design	Construction

Upper Mississippi River System Ecosystem Restoration Objectives

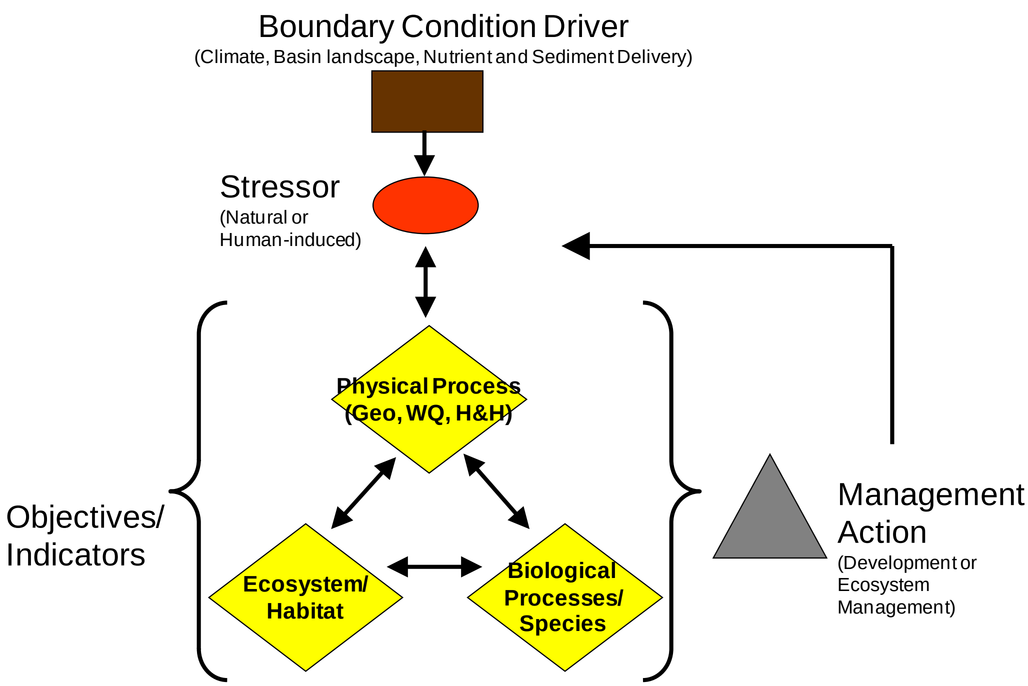


Chapter 3

UPPER MISSISSIPPI RIVER RESTORATION
ENVIRONMENTAL MANAGEMENT PROGRAM
ENVIRONMENTAL DESIGN HANDBOOK

CHAPTER 3

ECOSYSTEM RESTORATION OBJECTIVES



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CHAPTER 3

ECOSYSTEM RESTORATION OBJECTIVES

FIGURES

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CHAPTER 3

ECOSYSTEM RESTORATION OBJECTIVES

A. INTRODUCTION

Planning to identify Upper Mississippi River System (UMRS) ecosystem restoration program objectives has progressed from site specific project identification (DeHaan et. al. 2003) to a more comprehensive regional Habitat Needs Assessment (HNA; USACE, 2000), and most recently to the “Reach Planning” process which aspired toward adaptive management (USACE, 2011). The adaptive management philosophy first recommended by expert panels on the Upper Mississippi River Restoration Environmental Management Program (UMRR-EMP) System Ecological Team (EMP, 2003) and Navigation Study Science Panel (Barko et al., 2006) has been adopted by multiple UMRS ecosystem restoration programs and is now included in Corps policy (WRDA 2007; Section 2039; Appendix 3-A). The UMRS adaptive management process emphasizes several significant phases (Fischenich et al. 2012; figure 3-1):

1. System Scale Adaptive Management
2. Project Scale Adaptive Management Planning (e.g. Set-Up)
3. Adaptive Management Implementation.

Adaptive Management at the UMRS system scale includes large scale objectives and broad concepts for restoration, Williams et al. 2012 describe a “deliberative phase” that occurs infrequently in the duration of a program or agency planning. System scale ecosystem restoration planning occurred in 1986, 1997, 2003, and 2009. Adaptive management at the project scale was described as an “iterative phase” by Williams et al. 2012). Project planning includes: refined restoration criteria, preliminary design, and alternative analysis including physical process and ecological benefit assessment models. Adaptive management monitoring and evaluation may be emphasized for lesser known restoration techniques, but well known restoration actions proceed with less monitoring. Adaptive management implementation includes final design, construction, monitoring, and feedback loops that require assessment of project effects and learning objectives.

Several science review panels and program level planning exercises recognized the importance of restoration at multiple scales. Addressing restoration from a process and function perspective at ecologically relevant spatial scales (e.g., pool, reach, UMRS) in addition to the more traditional local project-based approach of directing efforts to restoring compositional and structural elements at individual sites is required for success at achieving social-ecological sustainability (Galat et al., 2007). A system-wide approach emphasizes restoring ecosystem functions and processes (e.g., landform evolution, plant community succession) over ecosystem structure (e.g., pattern of habitats, life forms) at individual project areas. A system-wide approach ensures logical connections among vision, goals, and objectives at different scales. This approach will strengthen the scientific basis for ecosystem restoration efforts, provide clear linkage across scales of the system, provide a logical basis for identifying and sequencing projects, and will support adaptive ecosystem management.

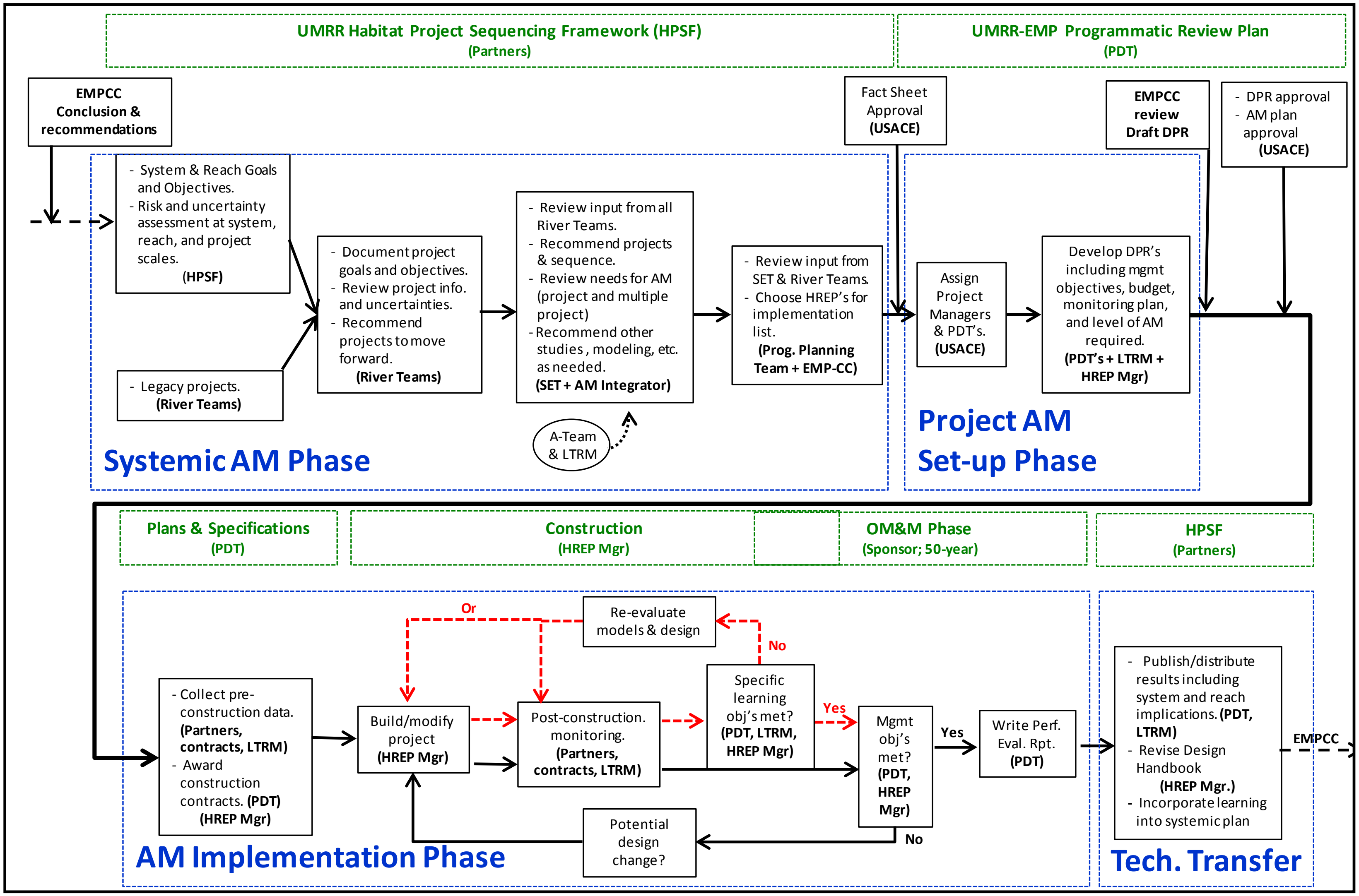

Figure 3-1. UMRS Adaptive Management (AM) Conceptual Model

Goals and objectives for condition of the river ecosystem are central to UMRS ecosystem restoration planning and adaptive ecosystem management (figure 3-2). Goals and objectives are logically linked to management actions, indicators of ecosystem conditions, monitoring activities, reporting on ecosystem conditions, and learning. System goals and objectives were codified by river managers first in *a River That Works and a Working River* (UMRCC, 2000), then during planning for adaptive management implementation (USACE, 2008) and most recently when establishing system-wide ecosystem restoration objectives USACE, 2011). Scientists supported the managers and helped refine planning strategies in *Establishing System-wide Goals, and Objectives for the Upper Mississippi River System* (Galat et al., 2007). The reach scale objectives are the product of river managers and scientists working as regional teams to emphasize unique physical and ecological characteristics and needs (USACE 2011).

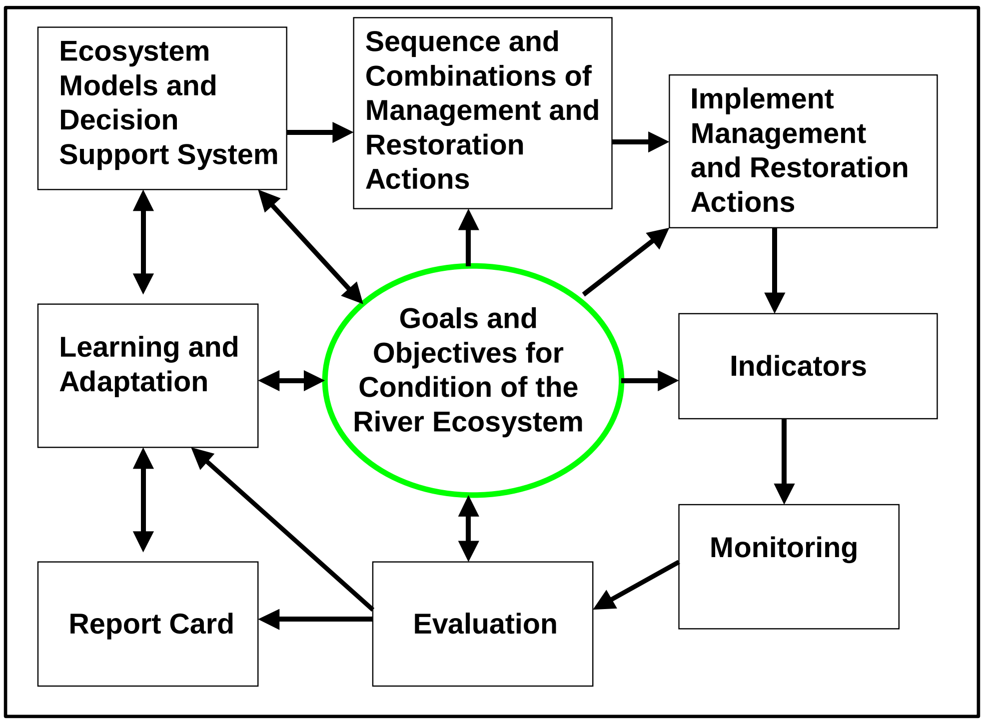

Figure 3-2. Goals and Objectives Central to the UMRS Adaptive Ecosystem Management

B. ADAPTIVE ECOSYSTEM MANAGEMENT

Adaptive management is a process that promotes flexible decision making that can be adjusted as outcomes from restoration actions and other events become better understood (Williams et al. 2007). Adaptive management is a process that uses management and restoration actions as tools to probe the functioning of an ecosystem. Kessler et al. (1992) note that in adaptive management, information from monitoring is used to continually evaluate and adjust management relative to predicted responses, management objectives, and predetermined thresholds of acceptable change. Partner derived goals and objectives are nearly always the recommended starting point for adaptive management (Galat et al., 2007). UMR System-wide goals established by the UMR Conservation Committee (UMRCC) in 2000 were reviewed and codified by a science review panel with the UMRR-EMP-Coordinating Committee in 2008 and future system scale planning will be reviewed by the

UMRR-EMP System Ecological Team. Established system goals make it easier for reach planning teams (i.e., Fish and Wildlife Work Group, Fish and Wildlife Interagency Committee, River Resources Action Team, and Illinois River Work Group) to identify locations that support the reach scale process and functions required to meet their regional objectives (USACE, 2011). Project objectives were established for many high priority sites recommended during the most recent collaborative planning process.

Adaptive management at the project scale begins with biologists and natural resource managers establishing restoration objectives and initial design criteria and engineers sizing structures, channels, dredging, etc. to achieve them. Project scale adaptive management increasingly uses process-based hydraulic models and wind-wave models to support project alternative analysis. Habitat suitability models are being refined by more closely integrating physical process models for better estimates of project effects. Habitat evaluation procedures, regional species models (bluegill overwintering), and regional community models (WHAG and AHAG) have been used most frequently for Habitat Rehabilitation and Enhancement Project (HREP) benefit analysis, but there has been increasing interest in improving regional models using Long Term Resource Monitoring (LTRM) data and prior HREP experience.

The project construction phase is an engineering led phase. Biologists have a role in construction monitoring to be sure constructed features are built according to plans, but also to take advantage of unique opportunities that might improve project features, ease operations, or save costs. Biologists monitoring construction can also observe early biological response, as some are immediate when river habitats are altered.

Monitoring is a critical learning phase that historically emphasized operation of constructed features and a few intensive biological response investigations. Adaptive management requires that monitoring is established to test hypotheses about the objectives developed during project design. Well known practices require less monitoring, new techniques need more monitoring to resolve uncertainty. Evaluation and assessment is an opportunity to "put it all together" and determine whether the actions achieved the desired outcome. Information learned during monitoring will ideally be used to modify existing restoration actions to improve future restoration efforts. Restoration actions deemed successful can be implemented efficiently using accepted criteria, as is the purpose of this Design Manual. Governance and program adaptation have been discussed in other documents, but it is important to be sure that learning is captured by the program and integrated into subsequent reviews of goals and objectives.

C. HIERARCHY OF VISION, GOALS, AND OBJECTIVES FOR THE RIVER ECOSYSTEM

Logical and scientifically-supported connections among vision, goals, and objectives are needed to ensure ecological and cost effectiveness of system management and restoration. Much effort has gone into establishing goals and objectives for the UMRS over the last 30 years. An initial Comprehensive Master Plan for the Upper Mississippi River Basin (UMRBA, 1982) established a baseline understanding of the condition of the entire system and system-wide economic, environmental, and recreational objectives. Since then iterative planning has emphasized different system components or was conducted in response to advances in knowledge or occurrence of extreme events, such as floods and droughts. The UMRS ecosystem restoration objectives have been reviewed many times in the context of multi-purpose navigation expansion and ecosystem restoration (USACE, 2004), ecosystem restoration (USACE, 2000), and river management (UMRCC, 2000) planning studies. Ecosystem restoration objectives were most recently stated as *Upper Mississippi River System Restoration Objectives 2009* (USACE, 2011) by interagency working groups representing state and federal natural resources agencies. These objectives evolved from the grassroots UMRCC 1994 Ecosystem Management Strategies (Grumbine 1984) in four separate river reaches to eventually be embraced by large river management programs including Navigation and Ecosystem Sustainability Program (NESP), UMRR-EMP, and Illinois River Basin Restoration, and the science community (Galat et al., 2007) as part of the NESP Science Panel. The cumulative work of many planning studies has resulted in a hierarchy of vision, goals, and objectives for the UMRS ecosystem developed with UMRS natural resource managers:

1. **Vision Statement.** The UMRS vision statement provides the foundation for goals and objectives and sets the broad direction and sideboards for future ecosystem restoration work (USACE, 2004). The vision statement is:

To seek long-term sustainability of the economic uses and ecological integrity of the Upper Mississippi River System

Adopting *ecological integrity* as a part of a vision statement for the UMRS means targeting a system that resembles its natural state as much as possible with minimal influence from human actions. While guidance and policy emphasize restoring natural conditions, in many cases it may only possible to achieve a partial restoration of natural processes on the UMRS, since it is a highly altered ecosystem and many of the changes to the river, floodplain, and watershed are irreversible. A system-wide approach is also process based, rather than site based. Restoring ecosystem structure and function and using natural processes has been effective to achieve sustainable restoration projects that should be more resilient to human and natural disturbances. The success of restoration planning increased as experience and learning helped identify key ecological functions and processes within the UMRS which have been incorporated into project design and system goals and objectives at all levels.

2. **Overarching Ecosystem-wide Goal.** The NESP developed the following overarching ecosystem-wide goal.

To conserve, restore, and maintain the ecological structure and function of the Upper Mississippi River System to achieve the vision of the Navigation and Ecosystem Sustainability Program

This goal implies conserving the UMRS' remaining structure and function while restoring the degraded components to realize a sustainable UMRS (Galat et al., 2007).

3. **Ecosystem Goals.** The following ecosystem goals address the five Essential Ecosystem Characteristics (EECs) suggested by Harwell et al. (1999) as being fundamental to ecosystem function. The EEC for each goal is shown in parentheses.

1) **Hydrology and Hydraulics (H&H):** Manage for a more natural hydrologic regime
2) **Geomorphology:** Manage for functions that shape diverse and dynamic channels and floodplain
3) **Biogeochemistry:** Manage for more natural materials transport and processing functions

4) **Habitat:** Manage for a diverse and dynamic pattern of habitats to support native biota

5) **Biota**: Manage for viable populations of native species and diverse plant and animal communities

4. Reach Scale Ecosystem Objectives. UMRS Ecosystem Objectives, ie. Reach Objectives, were developed by river management teams in four river reaches (summarized in table 3-1) as part of recent interagency reach planning (USACE, 2011). They are organized by EEC and the river reach for which they apply. Also, the objectives were drafted as statements of the future condition of the ecosystem, rather than statements about restoration actions. No attempt was made to designate primary versus secondary objectives, nor actions to achieve them. During more detailed planning at the project scale, factors such as habitat scarcity, area of influence, special status species (i.e., threatened and endangered species), sustainability, and national significance can be considered.

5. Project Scale Objectives. Project objectives derive from one or more of the larger scale goals and objectives described above. However, each project area has its own unique characteristics and is affected by different factors requiring that Project Delivery Teams (PDTs) develop objectives specific to that project area. Project objectives and criteria are developed by PDTs composed of interagency technical specialists familiar with project areas and restoration planning. Objectives should be specific, measurable, actionable, results driven, and time bound (SMART). SMART objectives ensure that sufficient information is collected to evaluate ecosystem response and increase system understanding in an adaptive management framework.

Table 3-1. Upper Mississippi River System Ecosystem Restoration Objectives Organized By Essential Ecosystem Characteristics (H&H, Biogeochemistry, Geomorphology, Habitat, and Biota in Four Floodplain Reaches)

Upper Impounded Floodplain Reach	Lower Impounded Floodplain Reach	Unimpounded Floodplain Reach	Illinois River
HYDRAULICS & HYDROLOGY: Manage for a More Natural Hydrologic Regime			
A more natural stage hydrograph	A more natural stage hydrograph		A more natural stage hydrograph
Restored hydraulic connectivity		Restored hydraulic connectivity	
	Naturalize the hydrologic regime of tributaries		
	Increase storage & conveyance of flood water on the floodplain		
BIOGEOCHEMISTRY: Manage for Processes That Input, Transport, Assimilate, & Output Material Within UMR Basin River Floodplains: e.g., Water Quality, Sediments, & Nutrients			
Improved water clarity	Increased water clarity		
Reduced nutrient loading	Reduced nutrient loading from tributaries to rivers		
Reduced sediment loading from tributaries & sediment resuspension in & loading to backwaters	Reduced sediment loading & sediment resuspension in backwaters		Reduced sediment loading & sediment resuspension in backwaters. **NOTE:** There are several objectives dealing with tributary loading
Reduced contaminants loading & remobilization of in-place pollutants			
		Water quality conditions sufficient to support native aquatic biota & designated uses	Water quality conditions sufficient to support aquatic biota
GEOMORPHOLOGY: Manage for Processes That Shape a Physically Diverse & Dynamic River Floodplain System			
Restore rapids			
	Restored backwater areas		Restored backwaters
	Restored lower tributary valleys		
Restore a sediment transport regime so that transport, deposition, & erosion rates & geomorphic patterns are within acceptable limits	Restored bathymetric diversity, & flow variability in secondary channels, islands, sand bars, shoals & mudflats	Restored bathymetric diversity, & flow variability in secondary channels, islands, sand bars, shoals & mudflats	Restored secondary channels & islands
	Restored floodplain topographic diversity		
			Restored lateral hydraulic connectivity

Table 3-1. Upper Mississippi River System Ecosystem Restoration Objectives Organized By Essential Ecosystem Characteristics (H&H, Biogeochemistry, Geomorphology, Habitat, and Biota in Four Floodplain Reaches)

Upper Impounded Floodplain Reach	**Lower Impounded Floodplain Reach**	**Unimpounded Floodplain Reach**	**Illinois River**
HABITAT: Manage for a Diverse & Dynamic Pattern of Habitats to Support Native Biota			
Restored habitat connectivity	Restored habitat connectivity		Restored habitat connectivity
Restored riparian habitat	Restored riparian habitat	Restored riparian habitat	
Restored aquatic off-channel areas		Increase the extent & number of sand bars, mud flats, gravel bars, islands, & side channels towards a more historic abundance & distribution.	
Restored terrestrial floodplain areas			
Restored channel areas			
	Diverse & abundant native aquatic vegetation communities (SAV, EAV, RFV)		
		Restored large contiguous patches of native plant communities to provide a corridor along the UMR	Restored floodplain areas
		Restored floodplain wetland areas	
		Restored degraded & rare native habitats	
			Restored lower tributary valleys
BIOTA: Manage for Viable Populations of Native Species Within Diverse Plant & Animal Communities			
Diverse & abundant native aquatic vegetation communities (SAV, EAV, R/F)			
Diverse & abundant native floodplain forest & prairie communities			
Diverse & abundant native fish community		Diverse & abundant native fish community	
Diverse & abundant native mussel			
Diverse & abundant native bird community			
	Restored diversity & extent of native communities throughout their range in the UMRS	Viable populations of native species throughout their range in the UMRS at levels of abundance in keeping with their biotic potential	Viable populations of native species throughout their range in the UMRS at levels of abundance in keeping with their biotic potential
	Reduced adverse effects of invasive species	Reduced adverse effects of invasive species	
			Restored diversity & extent of native communities throughout their range in the UMRS

D. ECOSYSTEM CONCEPTUAL MODELS

Modeling and understanding ecological mechanisms are important for all phases of restoration project planning, but especially early in project planning when objectives are established. Ecosystem conceptual models are important first steps in restoration project planning (Fischenich, 2008; Gentile et al., 2001; Ogden et al., 2005) to help define the system, identify important physical attributes, characterize system condition and potential, and to formulate project design and evaluation. Estimating environmental benefits and outcomes using models are important elements of adaptive management (Harwell, 1998) and project evaluation (USACE, 2000 Planning Guidance). Simple conceptual models have been referenced on the UMRS formally since the Great River Environmental Action Teams (GREAT I and II, UMRBC, 1982) and at the early stages of UMRR-EMP (Lubinski, 1993). They have continued to be used to categorize system-wide objectives (USACE, 2011) and to focus in on specific reaches and subareas with more detailed models. Ideally planners and designers try to organize ecological parameters and relationships that can be manipulated in relevant spatial analyses using multiple historic, contemporary, and modeled reference condition data (Nestler et al., 2010, Theiling and Nestler, 2010).

A simple ecosystem conceptual model (figure 3-3) can be used to illustrate that the five UMRS ecosystem goals are interrelated and that the physical/chemical processes usually impact Habitat and Biota, but that there are also feed-back loops. Figure 3-4 is used to illustrate linkages among drivers, stressors, UMRS EECs (H&H, Geomorphology, Biogeochemistry, Habitat, and Biota) and indicators (Lubinski and Barko, 2003). The model considers boundary condition drivers like glacial geology and climate that establish general ecosystem characteristics at the larger scales. There are numerous natural and anthropogenic stressors that perturb ecosystems and cause spatial and temporal variation throughout the river-floodplain system. Some are minor seasonal stressors like floods or cold weather, others are extreme natural events like great floods, droughts, or fire that are uncommon but strongly influence ecosystems. Human caused stressors include large, permanent physical changes like dams, levees, and urbanization as well as smaller disturbances like local land clearing or channel modifications whose cumulative impacts may cause large change.

Eight conceptual models were developed by the NESP Reach Planning Team for Geomorphic Reach 1. Figure 3-5 illustrates the framework used for the conceptual models. These floodplain reach scale conceptual models illustrate the linkage among ecosystem objectives, performance criteria, and indicators categorized by EECs (H&H, Geomorphology, Biogeochemistry, Habitat, and Biota). Essentially, this was done by first listing the Biota objective, then stressors affecting biota, and then listing Biogeochemistry, H&H, Geomorphology, and Habitat objectives and performance criteria that need to be met to achieve the biota objectives. In some cases, the objective from table 3-1 was made more specific (e.g. diverse and abundant native fish objective was made specific to lentic fish or lotic fish).

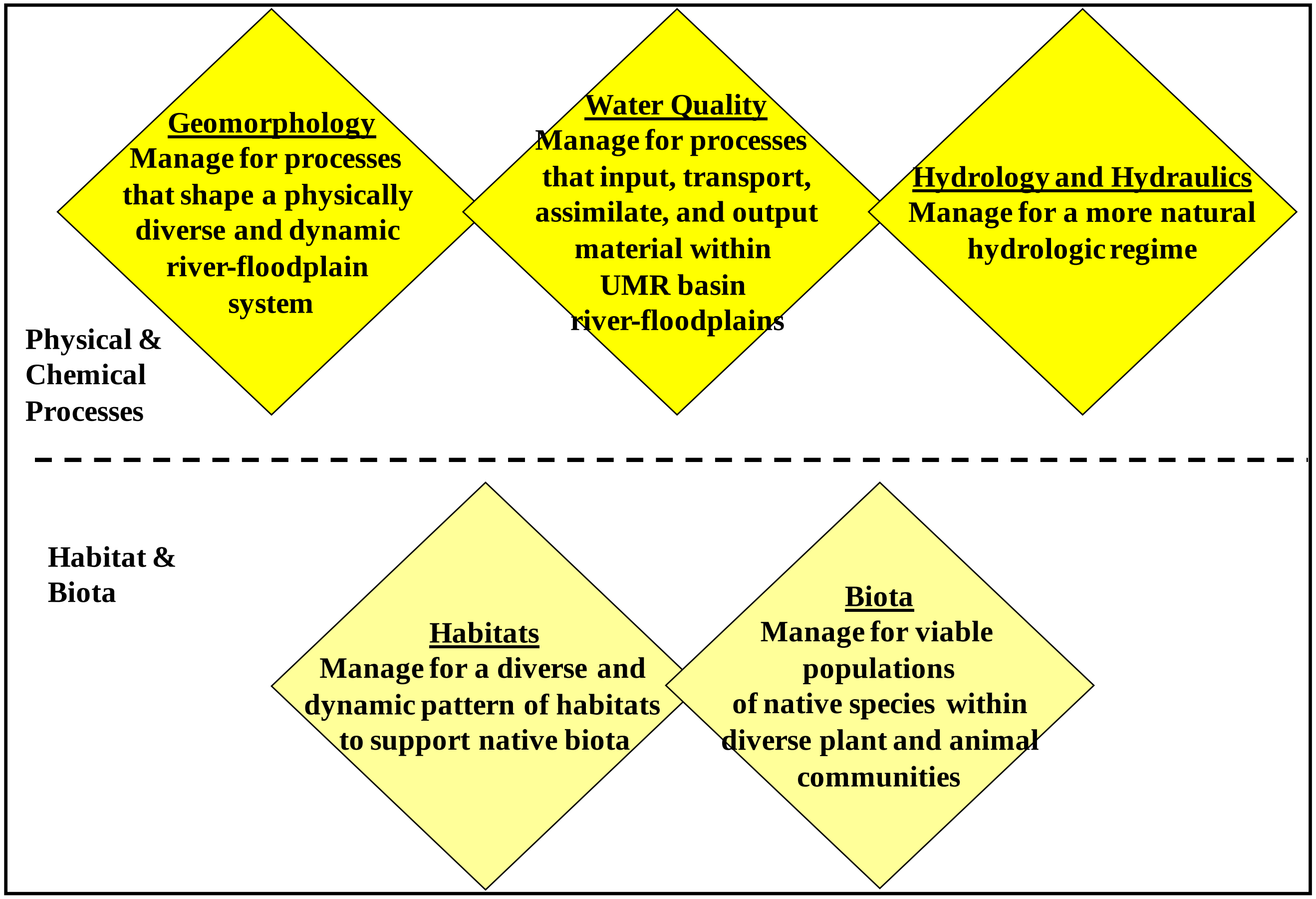

Figure 3-3. Upper Mississippi River System Essential Ecosystem Characteristics and objectives for their condition interact mostly as physical processes and structure (geomorphology, biogeochemistry, H&H) influencing habitat and biological outcomes.

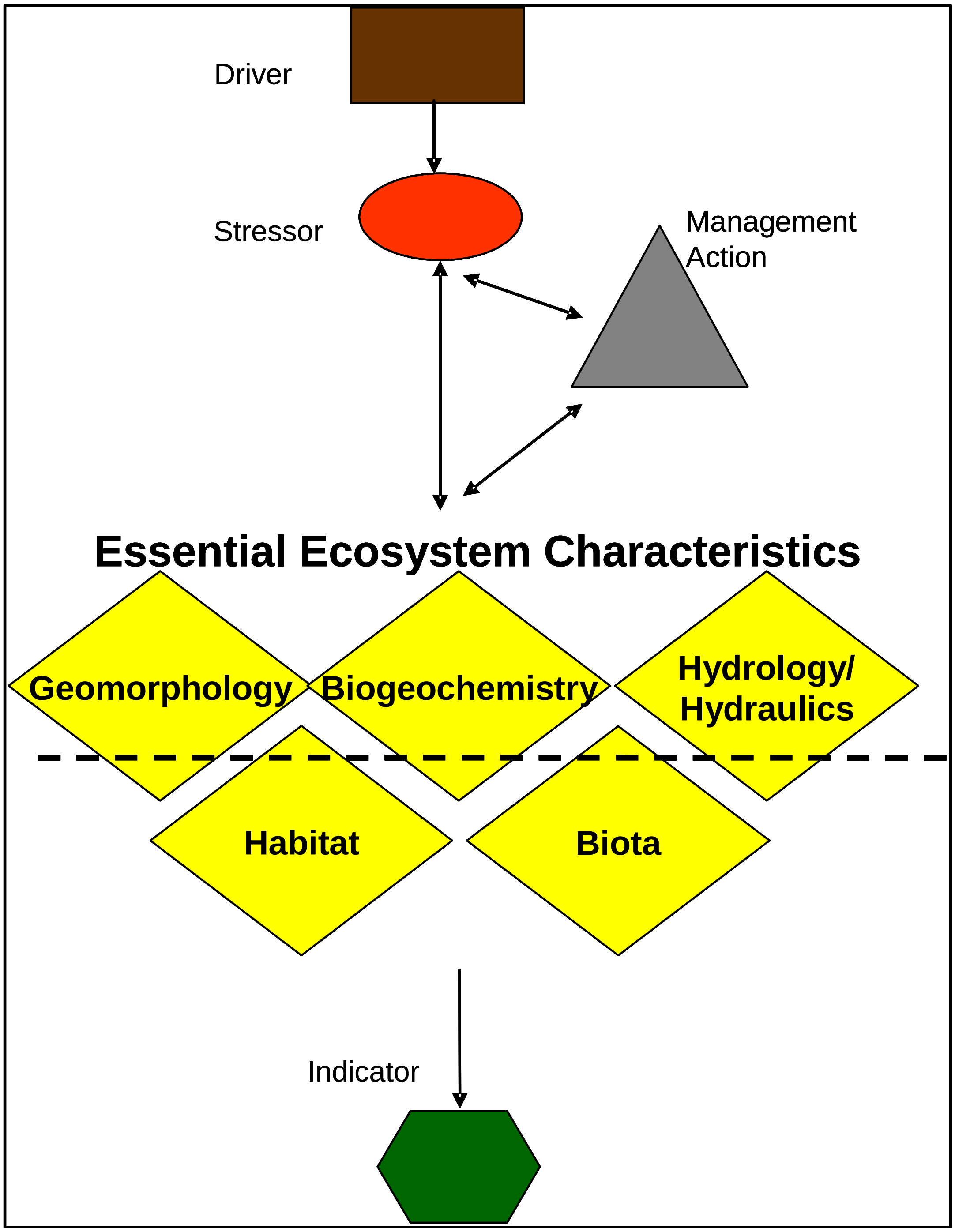

Figure 3-4. Upper Mississippi River System Ecosystem Conceptual Model

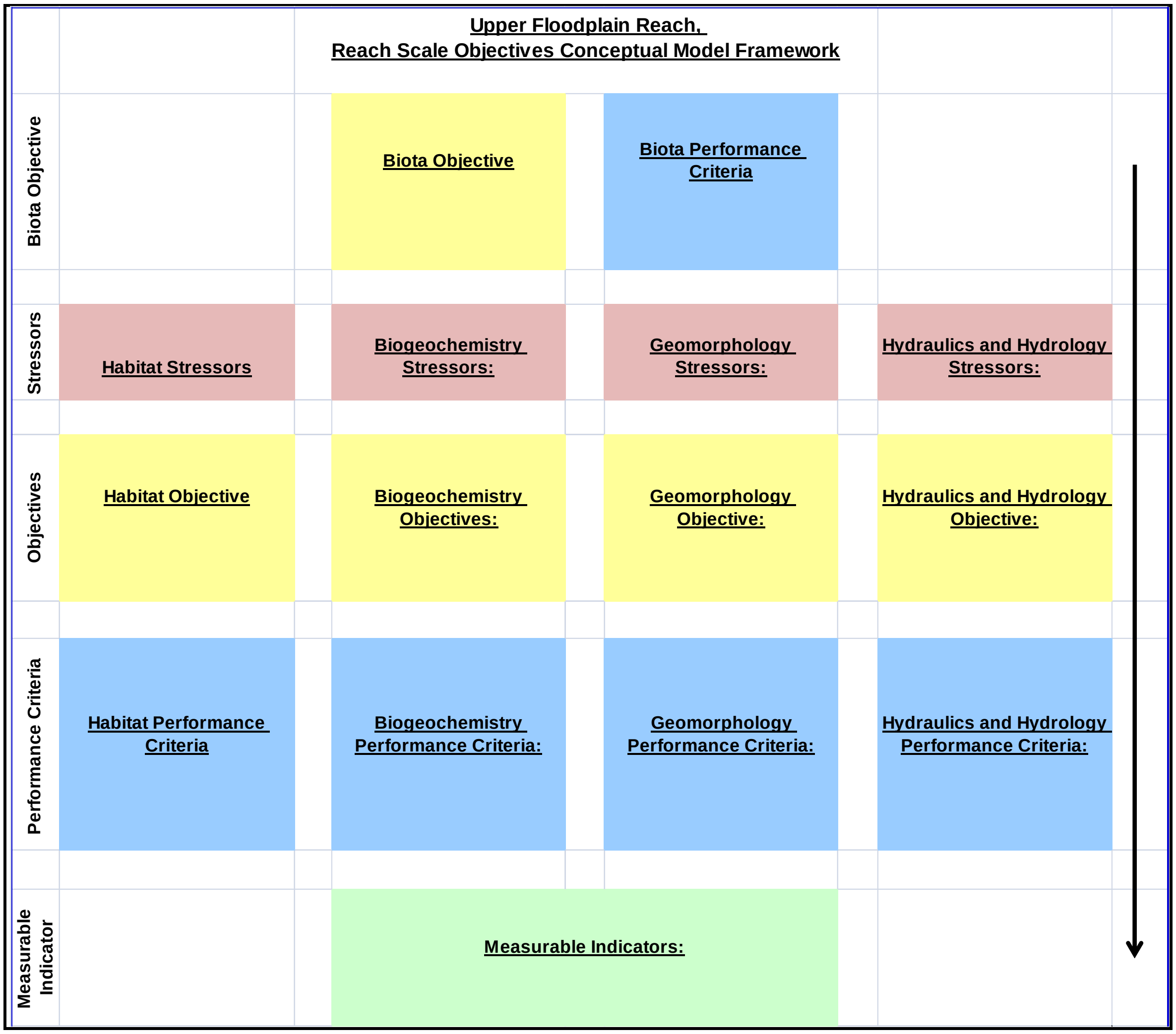

Figure 3-5. General Conceptual Model for Project Scale Use Helps Illustrate Planning and Analysis Detail

E. ADAPTIVE MANAGEMENT AT THE PROJECT SCALE

The relationship among habitat and biota and physical/chemical processes is partially captured within the conceptual models that have been developed, however the detailed analysis that is needed to improve on the conceptual models and previous spatial analysis will be done once planning and design is initiated on individual projects.

The physical/chemical parameters that consistently showed up in the conceptual models include water level variation (annual and daily), connectivity (both H&H and habitat), and sediment loads either from tributaries to the mainstem or from channels to off-channel areas. All of these parameters may be, and historically have been, altered using restoration actions. Quantifying the existing condition of each of these parameters in project areas and comparing these values to the target future condition is an important step in identifying restoration actions appropriate for a project area. Additional abiotic and biotic parameters will be considered at the project scale to describe habitats, biotic interactions, processes etc.

The linkage between the physical/chemical parameters and the habitat and biota objectives illustrated by the conceptual models helps to inform decision making. Any restoration action or combination of actions can be assessed as to whether the physical/chemical parameters would be moved in the desired direction and whether the desired response in biota is likely to be achieved. Figure 3-6 is a conceptual model illustrating the relationship among project scale habitat objectives, performance criteria, and management actions. In this figure, the project scale habitat objective (diving duck migratory habitat) can be achieved only if certain physical, chemical, and biological criteria are met. These criteria are organized by the EECs of geomorphology, H&H, biogeochemistry, and biota. Management actions that might be taken to meet the criteria and achieve the habitat objective are shown in the boxes on the right side of the diagram. Essentially the management actions alter the geomorphic (connectivity and wind fetch) or H&H (water level variation) characteristics of the project area, to improve biogeochemistry (water clarity) so that that aquatic vegetation will be at optimal levels and provide the needed food requirements for diving ducks during migration. For the sake of clarity, most of the detailed information was left out of this diagram. The PDT working on a project can develop information such as the number of acres of habitat to restore, or the required reduction of inflows or wind fetch. In this conceptual model, island construction could be used to meet several of the geomorphic and H&H criteria.

Conceptual models for islands and the associated biota have evolved through the 1990s to the present in the planning, design, construction, monitoring, and learning experience associated with the award winning Pool 8 Island HREP. Conceptual models were improved as ecosystem simulation models as LTRM and US Fish and Wildlife Service scientists developed a dabbling duck model in 1998 (Fox 1998) to estimate the benefits of islands from Phase I of the project. They then improved simulation models to incorporate other aspects of the conceptual model. The critical physical parameters were wind generated wave effects and river flow from hydraulic models. The improved models then informed the design of the final phase of construction and all the experience gained regarding design, construction, and management are immediately transferable to similar projects. The Pool 8 Islands HREP, and many other projects, has been a test bed for adaptive management implementation derived over 20 years of partnership among managers, scientists, engineers, and the public.

Figure 3-7 is a conceptual model for floodplain forests. It is formatted differently than figure 3-6, but is built on the same principle of linking project scale habitat objectives, performance criteria, and management actions. Determining a common conceptual model for the UMRS has been challenging because each team benefits from building their own models together. Variety drives diversity and innovation, but makes tracking and integration more difficult. This particular model is developed for Reno Bottoms, Minnesota (Pool 9) where hydrologic alterations to spillways and connecting channels could maintain forest diversity. This model and similar efforts at the Huron Island HREP assess the benefits of altering water table and tree elevation relationships. These objectives can be achieved by many actions associated with other Corps projects as well. Dam regulation can be altered to change groundwater stage and channel maintenance activity can generate fill to increase floodplain topographic diversity for example.

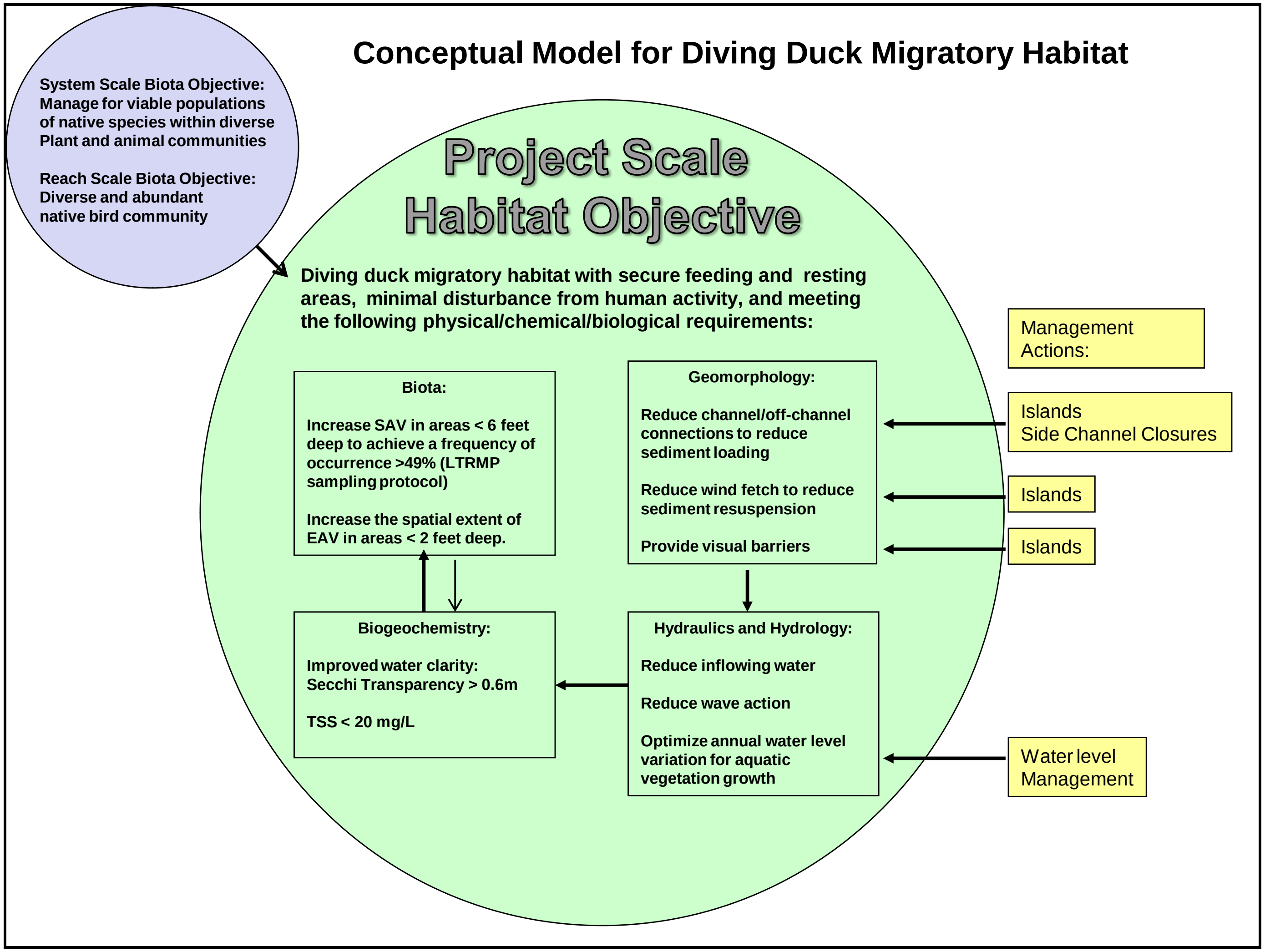

Figure 3-6. Conceptual Model for Diving Duck Migratory Habitat Used To Illustrate the Relationship Among Objectives, Performance Criteria, and Management Actions

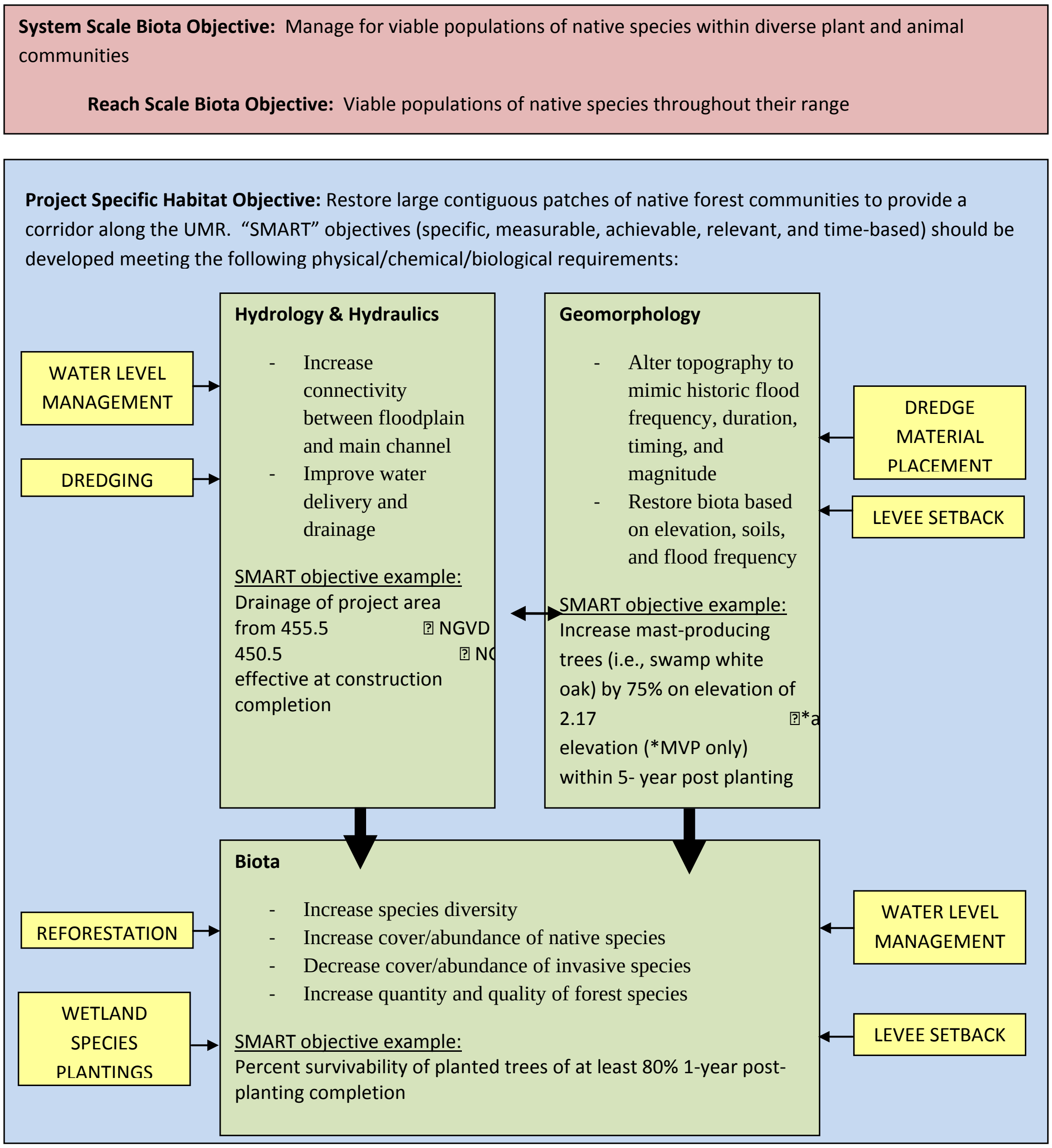

Figure 3-7. Conceptual Model for Floodplain Forest Habitat Used To Illustrate the Relationship Among Objectives, Performance Criteria, and Management Actions

Widespread use of conceptual models can help identify relationships among organisms, habitats, and operations that go undetected without a broad perspective. Several recent UMRS adaptive management studies have emphasized conceptual models for large system-wide issues. A draft report for a Pool 18 adaptive management plan for water level management identified conceptual frameworks and studies that could support learning about ecosystem response to drawdowns (USACE 2010). Similarly, a science workshop regarding side channel management in the Middle Mississippi reach also relied heavily on conceptual modeling to illustrate stakeholder visions for the functions supported by side channel habitats (Nestler et al. 2011).

1. Management Actions. PDTs consider unique and important ecosystem characteristics, factors limiting natural processes and the distribution and abundance of biota, project objectives, and performance criteria to develop management actions. The list of objectives and performance criteria that have to be met often suggests that multiple actions need to be taken at spatial scales including the project area, navigation pool, and watershed scales, but UMRR-EMP authorizing language and implementation considerations focus on the project area scale. Physical/chemical parameters that can be directly altered by restoration actions include hydrologic connectivity, seasonal water level variation, topography & bathymetry, wind fetch, bed roughness, bank erodibility, and substrate size. Altering these parameters affects many other physical, chemical, and biological processes. For example, reducing wind fetch reduces sediment resuspension, increases light penetration, increases submerged aquatic vegetation growth, and feeds ducks. Other management actions may be taken that directly affect biota, such as reforestation, managing aquatic nuisance species, and regulating fish and game harvests. Since the project scale objectives and performance criteria describe a partial restoration of natural conditions (e.g., more water level variation, altered connectivity, reduced wind fetch, reduced constituent loads, restoration of habitat quality and distribution, etc.), attaining these objectives will directly contribute to restoring natural river processes. Table 3-2 lists some management actions that might be taken to achieve objectives.

Table 3-2. Linking Ecosystem Objectives and Restoration Actions

Objective	Restoration Action	
A more natural stage hydrograph	Pool-wide drawdown Backwater drawdown	Levee removal
Restored hydraulic connectivity	Backwater restoration Barrier island construction	Levee removal Flow manipulation
Increase storage and conveyance of flood water on the floodplain	Levee removal	Bridge approaches
Restored backwaters	Backwater dredging Plantings Island construction	Flow manipulation Drawdown
Restored secondary channels and islands	Dike alteration Flow manipulation Woody debris	Dredging Drawdown Island construction
Restore sediment transport regime so transport, deposition, and erosion rates and geomorphic patterns are w/ acceptable limits	Side-channel closures Seed island	Tributary sediment traps Flow manipulation
Improved water clarity	Wave dampening Side-channel closures Drawdown sediment consolidation	Plantings Island construction
Naturalize the hydrologic regime of tributaries		
Restored lower tributary valleys		
Reduced sediment loading and sediment resuspension in backwaters	Flow manipulation Wave dampening Drawdown sediment consolidation	Sediment trap Plantings
Restored lateral hydraulic connectivity	See above	
Water quality conditions sufficient to support native aquatic biota and designated uses		
Restored rapids	Channel border bar construction Side channel manipulation	Dam removal Chain-of-Rocks
Restored bathymetric diversity, and flow variability in secondary channels, islands, sand bars, shoals and mudflats	Flow manipulation	Dredging
Reduced nutrient loading from tributaries to rivers		
Reduced contaminants loading & remobilizing in-place pollutants	Use mechanical dredging rather than hydraulic	
Restored floodplain topographic diversity	Dredged material mgmt Flow manipulation/scour	Flow deflectors Island construction
Forest Plan, Floodplain Landscape	Timber stand mgmt Private lands mgmt	Plantings Floodplain restoration

2. Project Performance Criteria. Performance criteria associated with each objective should be developed to make the objective more specific and quantitative (e.g., secchi depth should exceed 60 cm in backwaters). Performance criteria are measurable attributes of ecosystem objectives e.g. acceptable range, thresholds, or limits; based on scientific understanding of target future ecological conditions (adapted from Harwell et al. 1999). Performance criteria should be adaptive and adjusted as new information becomes available. Developing performance criteria describing the desired condition of ecosystem parameters is important because it:

a. makes the objectives SMART,

b. represents the accumulated knowledge of river managers and scientists,

c. requires the PDT to assess physical/biological relationships, and

d. promotes project consistency with variation based on site specific conditions and learning opportunities, as opposed to personal design philosophy.

The inability to develop criteria because of a lack of knowledge represents a data need, or the opportunity to learn through adaptive management.

Connectivity, annual water level variation, floodplain elevations, and sediment concentrations are a few parameters that might need to be altered to improve ecosystem conditions. At the project scales where detailed data can be efficiently collected and monitored, additional criteria (e.g. water depth, amount of connected habitat, distribution of aquatic vegetation) will be developed by PDTs. Existing literature and knowledge and the experience of PDT members can be used to quantify these parameters. As is typical in many ecosystems, less is known about the biota than the abiotic conditions, resulting in greater uncertainty with regards to the appropriate rates, magnitudes, and variations for describing processes associated with biota. Of particular importance for planning and designing restoration actions, is knowledge regarding the response of habitat and biota to changes in physical/chemical parameters (i.e. geomorphology, biogeochemistry, and H&H parameters). This is because restoration actions on the mainstem of the river directly alter these physical/chemical parameters to cause a desired response in habitat and biota.

3. Indicators. Ecosystem condition and response to management actions can be characterized by indicators (table 3-3) representing individual EECs or perhaps as a habitat or biological outcome reflecting the condition of several EECs. Physical structure and processes strongly influence habitat structure which supports plant and animal species, but there are also feedbacks (figure 3-3). The LTRM Status and Trends Report 2008 indentified the linkages among system-level objectives and the environmental parameters that they measure (Johnson and Hagerty 2008). LTRM data collection helps identify existing condition of H&H, Biogeochemistry, Geomorphology, Habitat, and Biota in the trend analysis reaches and beyond.

Table 3-3. Ecological Indicators Applicable At Several Spatial Scales For Upper Mississippi River System Essential Ecosystem Characteristics

	Boundary Condition	Reach Scale	Local Scale
Geomorphology	**Glacial Geology**	• land sediment assemblages • impoundment effects • levee effects • aquatic area change • geomorphic change	• elevation • soil • geomorphic change
H&H	**Climate/Discharge** • magnitude • frequency • timing • duration • rate of change	**Water Surface Elevation** • magnitude • frequency • timing • duration • rate of change	• flow distribution • direction • depth • velocity • inundation magnitude • frequency • timing • duration • rate of change • pool scale hydrologic gradient
Biogeochemistry	• basin geology • basin land cover • non-point pollution	**Major Watershed** • geology • land cover • non-point pollution	• nutrient abundance • water clarity • dissolved oxygen • sediment quality • point source pollution • non-point pollution
Habitat	• climate • biodiversity • geomorphology • hydrology	• regional climate • eco-regions • land use • ecosystem/community type • disturbance	• land cover • ecosystem/community type • geomorphology • hydrology • aquatic areas
Biota	• biodiversity • long distance migrants	• populations • communities	• species composition
Biotic Processes	• biochemistry	• climate • genetics	• production • growth

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Appendix 3-A.

DEPARTMENT OF THE ARMY
U.S. ARMY CORPS OF ENGINEERS
441 G STREET NW
WASHINGTON, D.C. 20314-1000

CECW-PB

31 AUG 2009

MEMORANDUM FOR COMMANDERS, MAJOR SUBORDINATE COMMANDS

SUBJECT: Implementation Guidance for Section 2039 of the Water Resources Development Act of 2007 (WRDA 2007) – Monitoring Ecosystem Restoration

1. Section 2039 of WRDA 2007 directs the Secretary to ensure that when conducting a feasibility study for a project (or component of a project) for ecosystem restoration that the recommended project includes a plan for monitoring the success of the ecosystem restoration. The monitoring plan shall include a description of the monitoring activities, the criteria for success, and the estimated cost and duration of the monitoring as well as specify that monitoring will continue until such time as the Secretary determines that the success criteria have been met. Within a period of ten years from completion of construction of an ecosystem restoration project, monitoring shall be a cost-shared project cost. Any additional monitoring required beyond ten years will be a non-Federal responsibility. A copy of Section 2039 is enclosed.

2. Applicability. This guidance applies to specifically authorized projects or components of projects as well as to those ecosystem restoration projects initiated under the Continuing Authority Program (CAP) or other programmatic authorities.

3. Guidance.

a. Monitoring includes the systematic collection and analysis of data that provides information useful for assessing project performance, determining whether ecological success has been achieved, or whether adaptive management may be needed to attain project benefits. Development of a monitoring plan will be initiated during the plan formulation process for ecosystem restoration projects or component of a project and should focus on key indicators of project performance.

b. The monitoring plan must be described in the decision document and must include the rationale for monitoring, including key project specific parameters to be measured and how the parameters relate to achieving the desired outcomes or making a decision about the next phase of the project, the intended use(s) of the information obtained and the nature of the monitoring including duration and/or periodicity, and the disposition of the information and analysis as well as the cost of the monitoring plan, the party responsible for carrying out the monitoring plan and a project closeout plan. Monitoring plans need not be complex but the scope and duration should include the minimum monitoring actions necessary to evaluate success. The appropriateness of a monitoring plan will be reviewed as part of the decision document review including agency technical review (ATR) and independent external peer review (IEPR), as necessary. The estimated cost of the proposed monitoring program will be included in the project cost estimate and cost-shared accordingly.

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SUBJECT: Implementation Guidance for Section 2039 of the Water Resources Development Act of 2007 (WRDA 2007) – Monitoring Ecosystem Restoration

c. Upon completion of the construction of the ecosystem restoration project (or component of a project), monitoring for ecological success will be initiated. Monitoring will be continued until ecological success is determined. Once ecological success has been documented by the District Engineer in consultation with the Federal and State resources agencies, and a determination has been made by the Division Commander that ecological success has been achieved (may be less than ten years), no further monitoring will be required. Ecological success will be documented through an evaluation of the predicted outcomes as measured against the actual results. The law allows for but does not require a 10 year cost shared monitoring plan. Necessary monitoring for a period not to exceed 10 years will be considered a project cost and will be cost shared as a project construction cost and funded under Construction. Costs for monitoring beyond a 10 year period will be a non-Federal responsibility. Financial and implementation responsibilities for the monitoring plan will be identified in the Project Partnership Agreement. For CAP projects, or for those projects that may be authorized with an explicit dollar cap, any cost shared monitoring costs cannot increase the Federal cost beyond the authorized project limit of the CAP or other authority under which the project is being considered.

d. Contingency Plan (Adaptive Management). An adaptive management plan (i.e., a contingency plan) will be developed for all ecosystem restoration projects. The adaptive management plan must be appropriately scoped to the scale of the project. If the need for a specified adjustment is anticipated due to high uncertainty in achieving the desired outputs/results, the nature and cost of such actions should be explicitly described in the decision document for the project. The reasonableness and the cost of the adaptive management plan will be reviewed as part of the decision document. Costly adaptive management plans may indicate the need to reevaluate the formulation of the ecosystem restoration project. The information generated by the monitoring plan will be used by the District in consultation with the Federal and State resources agencies and the MSC to guide decisions on operational or structural changes (adaptive management) that may be needed to ensure that the ecosystem restoration project meets the success criteria. The adaptive management plan cost should be shown in the 06 feature code of the cost estimate.

If the results of the monitoring program support the need for physical modifications to the project, the cost of the changes will be cost shared with the non-Federal sponsor and must be concurred in by the non-Federal sponsor. The appropriate HQUSACE RIT should be advised at such time that it is determined a modification to a project is required. Any changes to the adaptive management plan approved in the decision document must be coordinated with HQUSACE at the earliest possible opportunity. If a needed change is not part of the approved adaptive management plan and is determined by HQUSACE to be a deficiency correction the annual budget guidance to initiate a study for such corrections should be followed. Significant changes to the project required to achieve ecological success and which cannot be appropriately

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addressed through operational changes or through the approved adaptive management plan may need to be examined under other authorities, such as Section 216, River and Harbor and Flood Control Act of 1970.

4. This guidance is effective immediately and will be incorporated into ER 1105-2-100 upon the next revision.

FOR THE COMMANDER:

Encl

THEODORE BROWN, P.E.
Chief, Planning and Policy Division
Directorate of Civil Works

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CECW-NWD
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CECW-NAD
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SEC. 2039. MONITORING ECOSYSTEM RESTORATION.

(a) In General- In conducting a feasibility study for a project (or a component of a project) for ecosystem restoration, the Secretary shall ensure that the recommended project includes, as an integral part of the project, a plan for monitoring the success of the ecosystem restoration.

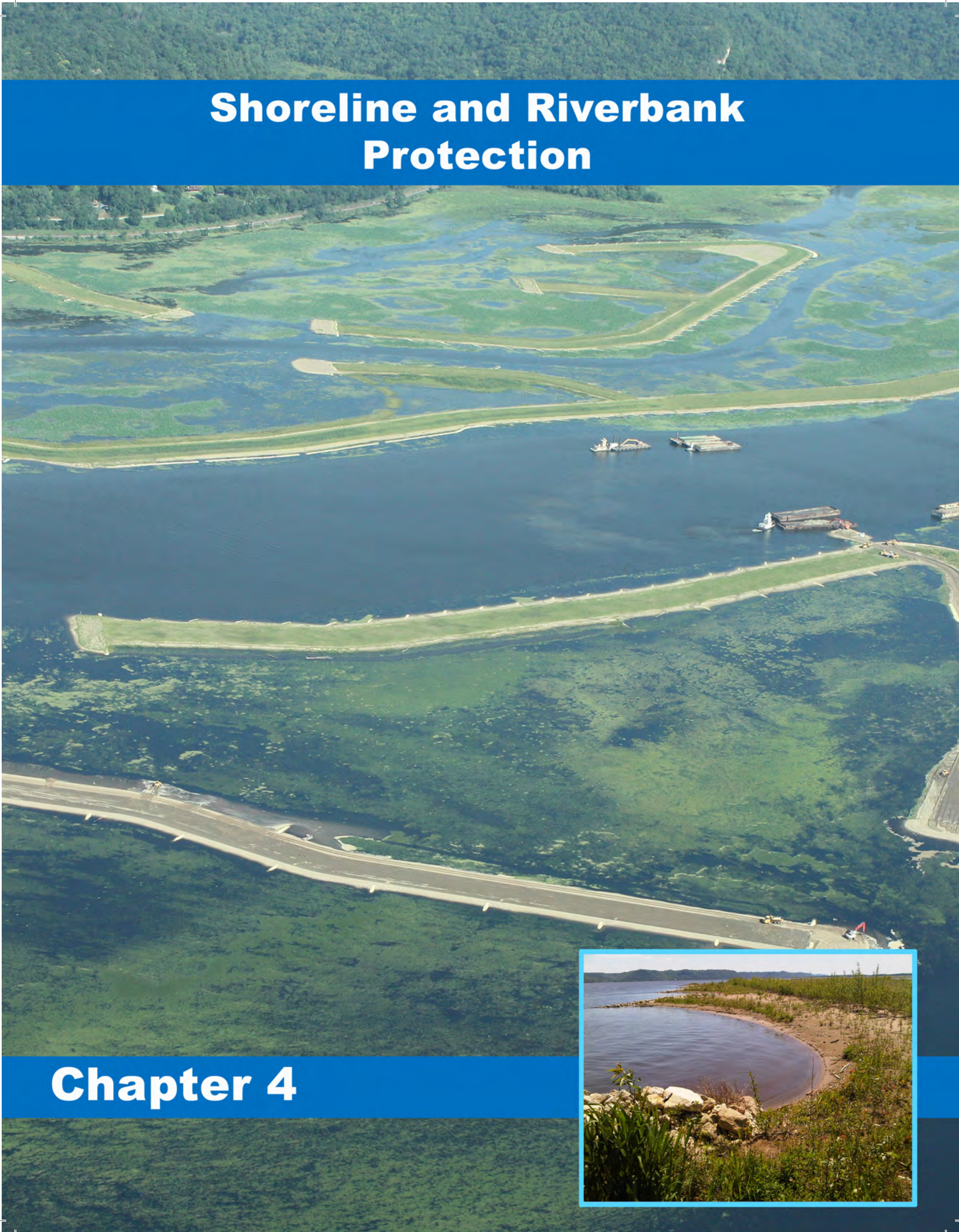
(b) Monitoring Plan- The monitoring plan shall--

(1) include a description of the monitoring activities to be carried out, the criteria for ecosystem restoration success, and the estimated cost and duration of the monitoring; and

(2) specify that the monitoring shall continue until such time as the Secretary determines that the criteria for ecosystem restoration success will be met.

(c) Cost Share- For a period of 10 years from completion of construction of a project (or a component of a project) for ecosystem restoration, the Secretary shall consider the cost of carrying out the monitoring as a project cost. If the monitoring plan under subsection (b) requires monitoring beyond the 10-year period, the cost of monitoring shall be a non-Federal responsibility.

Shoreline and Riverbank Protection

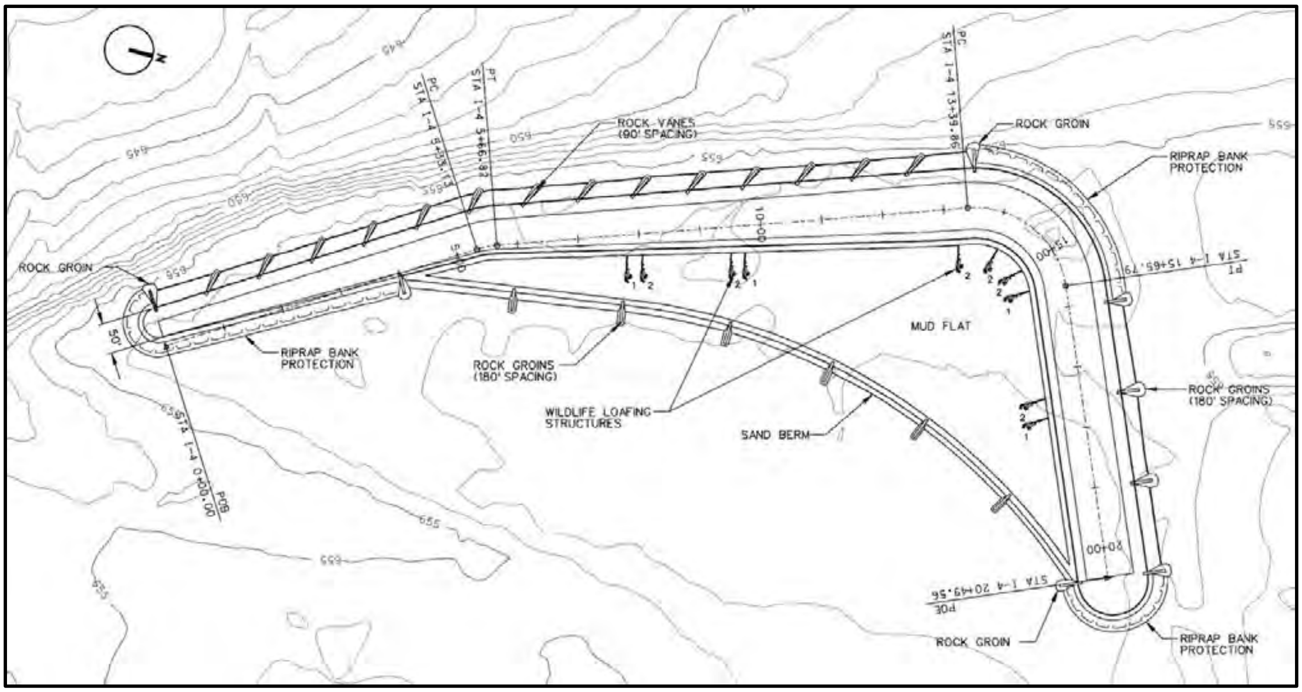


Chapter 4

UPPER MISSISSIPPI RIVER RESTORATION ENVIRONMENTAL MANAGEMENT PROGRAM ENVIRONMENTAL DESIGN HANDBOOK

CHAPTER 4

SHORELINE AND RIVER BANK PROTECTION



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UPPER MISSISSIPPI RIVER RESTORATION
ENVIRONMENTAL MANAGEMENT PROGRAM
ENVIRONMENTAL DESIGN HANDBOOK

CHAPTER 4

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CHAPTER 4

SHORELINE AND RIVER BANK PROTECTION

A. RESOURCE PROBLEMS AND OPPORTUNITIES

After the locks and dams were constructed in the 1930s, shoreline erosion increased due to exposure to erosive forces from wind driven wave action, river currents, and ice action. As islands eroded in the lower reaches of navigation pools, the amount of open water increased and the magnitude of the erosive forces increased. This was exacerbated by the loss of aquatic vegetation, which created even more open water. As this occurred, more shoreline was exposed and gave way to the erosive forces. This chapter provides methods for mitigating erosion of natural and newly constructed shoreline on the Upper Mississippi River.

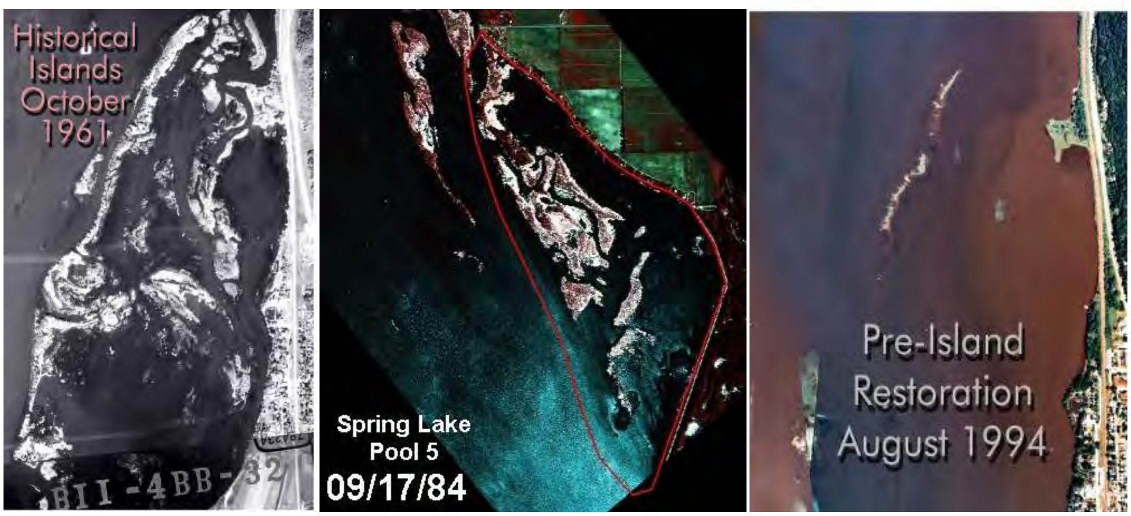
1. Pre-Inundation Conditions. The Upper Mississippi River is island braided with many anatomizing side channels, sloughs, backwaters, and islands (Collins & Knox, 2003). Natural levees separate the channels from the backwaters and floodplain. In its natural state, the flow of water and sediment was confined to channels during low flow conditions. For larger floods, the natural levees were submerged resulting in water and sediment conveyance in the floodplain, however channel conveyance continued to be high since floodplain vegetation increased resistance and reduced discharge in the floodplain. Geomorphic processes such as erosion, deposition, and channel migration was a natural process occurring at variable rates depending on river slope, floodplain size, geomorphic controls like tributaries or rapids, and sediment loads. By the 1930s, these geomorphic processes were significantly changed by the earlier attempts to establish a 4 ½ and later a 6 foot navigation channel. Training structures consisting of wing dams, closing dams, and bank revetments; along with dredge material placement was used to narrow and deepen the main channel of the river for navigation. Conversion of tributary watersheds to agriculture combined with the extremely poor practice of logging on hillside slopes resulted in elevated sediment loads in the tributaries, causing significant deposition in tributary floodplains, and in some instances increased sediment fluxes to the Mississippi River. Deforestation along the river to fuel steamboats in the 1800s and then later for agricultural and urban development, changed the riparian and floodplain areas significantly. Agricultural levee districts sequestered large areas of the floodplain from the river in south of Rock Island. All of these changes had some effect, in some cases de-stabilizing river banks, and in other cases actually stabilizing them. Some of these effects may have been masked by the fact that river discharges had been decreasing between 1880 and 1930.

2. Resource Problems. The river today is a reflection of many changes that have altered its natural condition (Chen & Simons, 1979, Collins & Knox, 2003). These include the early attempts to use the river for navigation and convert the watershed to agriculture, along with the urbanization of some reaches of the river, the introduction of aquatic nuisance species, and climate variation which has caused a trend of increased river discharges beginning in the 1930s and continuing to the present. In the impounded reaches of the river above St. Louis, Missouri, the construction of the Locks and Dams in the 1930s is the most significant event affecting shoreline and river bank stability and the condition of the river today.

Construction of the locks and dams submerged portions of the natural levees and floodplain creating navigation pools upstream of the dams and leaving only the higher parts of the natural levees as islands. The physical changes created by lock and dam construction produced a significant biological response in the lower reaches of the navigation pools. The original floodplain, which consisted of floodplain forests, shrub carrs, wetlands, and potholes, was converted into a large permanently submerged aquatic system. These areas are commonly called backwaters. A diverse assemblage of aquatic plants colonized the backwaters, with the distribution of plant species being a function of water depth, current velocity, and water quality. Fish and wildlife flourished in this artificial environment for several decades after submergence, however sediment deposition, permanent submergence, and shoreline erosion caused a gradual decline in the habitat that had been created in the backwaters.

In the navigation pools, shoreline erosion increased after lock and dam construction permanently raised water levels over the long term killed riparian trees. Tree uprooting in later years destabilized some river banks. Wave action and river currents are constantly acting on alluvial soils, previously in the riparian zone, that had only been subject to these forces during seasonal high water and were partly sheltered because of their location.

Wind fetch was immediately increased when the floodplain was inundated, and continued to increase as features in the lower halves of navigation pools disappeared. This process is shown in photograph 1.



Photograph 4-1. Degradation at Spring Lake, Pool 5

The transport of sediment was altered resulting in sediment deposition in the middle reaches of navigation pools, and reduced sediment loads to the lower reaches, which may have contributed to shoreline erosion.

3. Resource Opportunities. The increase in shoreline erosion is directly linked to the changes that have been made to the river as described in the previous section. In the lower reaches of navigation pools, this was exacerbated by the loss of natural islands and structure in the river through erosion. This structure is necessary to achieve the diversity in water depths, current velocities, and water quality desirable in channels and backwater areas.

Shoreline stabilization is used on new HREPs such as island shorelines or water level management projects and it is also used to stabilize existing shorelines that might be eroding. In areas where the natural structure has been lost, island construction can reverse or alter the impacts created by the locks and dams. On new projects, it is an added expense that is justified because of the investments made in the project. On existing shorelines, stabilization usually can only be justified if additional habitat besides the shoreline itself will be enhanced or preserved.

4. HREP Objectives. HREP features are designed with the intent of meeting specific project objectives. It is important for the design team to have an understanding of the relationship between project features and objectives to help maximum benefits and minimize costs. Also, many of the effects of these features occur secondarily to the obvious primary effects; understanding these relationships even at a basic level can help inform design decisions.

Table 3-1 in Chapter 3 of this Handbook shows many examples of non-specific objectives for HREPs categorized by Essential Ecosystem Characteristics. For actual projects, these objectives would be more focused, but they are useful here to help provide a basic understanding of how project features can be used to meet multiple objectives. Following is a discussion of each category, some of the objectives that can be addressed through shoreline protection features and their relationships are briefly discussed. It should be noted that this is not an all-inclusive list, but is being used here to facilitate consideration of the numerous relationships between features and objectives.

a. Hydraulics and Hydrology: Shoreline protection features generally do not directly affect hydrology, but their primary purpose is to modify hydraulics at the substrate/water interface to prevent erosion. By preventing erosion, shoreline protection features are used to maintain islands, which are often created or protected in order to support a certain level of lateral hydraulic connectivity (often maintaining a reduced level of lateral connectivity), often an important objective in HREPs.

b. Geomorphology: Shoreline protection features directly affect geomorphology. They contribute to maintaining topographic and bathymetric diversity objectives by helping to prevent erosion of high areas and, consequently, the sedimentation of deeper areas. They also contribute to maintaining flow and sediment transportation rates in side channels by assuring the existence of land masses that direct flows. When these features are used to maintain a relative lack of lateral connectivity by protecting barrier islands, they help reduce sedimentation in backwaters and, therefore, help meet bathymetric diversity objectives there. Features such as groins and vanes contribute directly to bathymetric diversity objectives in their immediate vicinities by their construction and the subsequent creation of scour holes in certain cases.

c. Biogeochemistry: Shoreline protection features indirectly affect biogeochemistry in many ways. Reducing suspended sediment loads by preventing erosion and directing the flow of sediment-laden water can reduce sediment and contaminant loading and improve water clarity, especially in backwaters. Increasing water clarity improves vegetation growth, which can affect nutrient processing and dissolved oxygen levels. Nutrient processing and dissolved oxygen are also affected by water exchange rates, which are controlled by lateral connectivity.

d. Habitat: Shoreline protection features affect habitat directly and indirectly, and these effects result from changes to the previous three categories discussed above. Shoreline protection features prevent the erosion and loss of terrestrial and riparian habitat such as bottomland forest. They also ensure the maintenance of similar created habitats such as islands. Because they prevent the loss of these habitats, they support aquatic habitat objectives that would be addressed by these features, especially those related to lateral connectivity.

The rock used in the construction of these features provides habitat for aquatic invertebrates and fish, but it can also create a hazard and a barrier for turtles and other riparian wildlife. The use of vegetation in stabilizing banks where appropriate can provide better riparian habitat, but groins and vanes are less intrusive than riprap may be a preferred compromise. Offshore rock mounds used to protect banks provide relatively unique protected wetland habitat between the mound and shoreline.

e. Biota: Shoreline protection features (and most features used in HREPs) indirectly affect biota through other effects to hydrology, geomorphology, biogeochemistry, and habitat. The effects to biota are seldom measurable in a manner that can clearly prove a cause and effect relationship with project features, so they are often assumed to correlate with physical habitat objectives.

B. MANAGEMENT ACTION

The primary forces that affect shorelines are river currents and wind driven wave action, though ice action and waves created by towboats or recreational boats can also cause erosion. The following techniques are used to mitigate the erosive forces and are further described in table 4-1:

- Riprap (Photograph 4-2)
- Bio-Geo methods (Photographs 4-3 and 4-4)
- Vegetative stabilization (Photograph 4-5)

These techniques can be employed singly or in combination to protect shoreline and add habitat diversity to the system. For example, more gradual side slopes and sand or mud soils can be beneficial to turtles, and waterbirds that nest, feed, and loaf on the shorelines. Native plantings are more aesthetically pleasing than traditional bank stabilization (i.e., riprap). Traditional stabilization techniques are also being reviewed to improve habitat benefits. Larger rock and mixed grade rock can create greater fish and invertebrate habitat diversity by providing bigger crevices for shelter and flow diversity (Report to Congress, 2004).

Photograph 4-2. Riprap and Geotextile Filter Placed on Sand (Lake Onalaska)

Photograph 4.3. Bio-Geo Stabilization with Groins and Willows (Boomerang Island)

Photograph 4-4. Vanes

Photograph 4-5. Vegetative Stabilization (Boomerang Island)

Table 4-1. Description of Shoreline Stabilization Techniques

Stabilization Technique	When To Use	Description	Advantages	Disadvantages
Rock Fill (no filter)	Remote site where erosive action is severe. If off-shore depths are greater than 5 ft deep, or if feature being protected has a convex shape in plan, rockfill should be considered. If ice action will occur, rock fill may be the best choice because of self-healing properties.	Rock fill increases the shear strength of the shoreline so that erosive forces do not displace shoreline substrate. The thickness and size of the riprap varies depending on the magnitude of the erosive force. Rock fill thickness is increased over the thickness of riprap so the layer is self-filtering. A 24-" layer is used in most situations.	Rock fill can be designed and placed so that a continuous thick layer of rock results. Its performance and cost can be predicted more reliably than some other methods, and because of the greater thickness, it has self healing properties in the event of ice action or toe scour.	Cost is relatively high (see figure 4-4) because stabilization relies on continuous coverage of the shoreline with rock. Creates an unnatural aquatic/terrestrial transition which may not be beneficial to some species.
Riprap w/ Filter	Easily accessible site with severe erosive action. If off-shore depths are greater than 5 ft, or if feature being protected has a convex shape in plan, rockfill should be considered.	Riprap increases the shear strength of the shoreline so that erosive forces do not displace shoreline substrate. The thickness and size of the riprap varies depending on the magnitude of the erosive force. Because riprap layer thickness is less than rock fill, a granular or geotextile filter is required to prevent loss of su4-grade material	Less volume of rock used so if cost per linear foot of filter is less than additional rock in a rock fill layer it is less expensive than rock fill with no filter.	Creates an unnatural aquatic/terrestrial transition which may not be beneficial to some species. If site is remote, transporting the filter material to the site may be difficult which adds to the cost.
Groins	Where erosive action is mainly due to wave action and off-shore depths are less than 3 ft at the end of the groin. Shoreline material type should consist primarily of sand-size material.	Long, narrow rock structures placed perpendicular to shorelines to contain littoral drift (i.e. the transport of sand along a shoreline due to wave action). This results in a scalloped shoreline shape (requiring a sacrificial berm), which is the shoreline adjustment to the prevailing winds. Used in conjunction with planted shoreline vegetation.	One of the lowest cost stabilization techniques. Does have a beach between groins, which is beneficial to some species. More natural looking	Vulnerable to ice action. Needs room for a sacrificial berm consisting of granular fill.
Vanes	Where erosive action is mainly due to river currents. Shoreline material type should consist primarily of sand-size material.	Long, narrow rock structures placed at an upstream angle to shorelines to redirect river currents away from the shoreline. Erosive secondary currents are moved away from the toe of the bank. Used in conjunction with planted shoreline vegetation.	One of the lowest cost stabilization techniques. More effective than groins if there are river currents. Retains a beach which is beneficial to some species. More natural looking	Vulnerable to ice action rock displacement by large woody debris. Needs room for a sacrificial berm consisting of granular fill.
Off-Shore Mounds	When off-shore water depths prevent equipment access to the shoreline being protected.	Long, narrow rock structures placed parallel to shorelines some distance off-shore to reduce erosive forces due to wave action, river currents, or ice action	Creates sheltered aquatic area between mound and shoreline.	High cost Cost effective only in shallow water.
Vegetative Stabilization	Vegetative stabilization can be used along shorelines where offshore velocities are less than 3 ft/sec, wind fetch is less than 1/2 mile, ice action and boat wakes are minimal, or where offshore conditions (depth or vegetation) reduce erosive forces.	Vegetative stabilization consists of plantings of woody tree species or seeding herbaceous vegetation. Other types of stabilization structures, such as groins or vanes, are not used.	Lowest cost stabilization technique In addition to stabilization, it creates habitat.	Limited to shorelines where erosive forces are minimal. Requires the vegetation to flourish. If vegetation is attacked by some type of pest and does not thrive, it will not be effective erosion control.

1. Site Identification. Typically, the project design team (PDT) works together to identify and prioritize areas requiring protection. Coordination with the project sponsor or resource agency is very important in evaluating shoreline erosion. For one project in Pool 18, there was no apparent visual bankline erosion during the site visit, however, based on information from the sponsor, a building foundation remnant was located which had once been 50 feet from the shoreline. At the time of the site visit, the foundation was located at the edge of the island. After researching real estate photograph from the 1930 land acquisition, it was apparent that erosion was occurring (photograph 4-6).

Photograph 4-6. Bankline Erosion at Huron Island, Pool 18 (note building foundation)

Other banklines have more apparent erosion that can be observed during site visits, such as the location in Pool 20 shown in photograph 4-7.

Photograph 4-7. Bankline Erosion on Long Island Division, Pool 20

Survey of banklines is also important in establishing erosion near proposed future features. For accurate survey to be used in computer modeling software such as Bentley Inroads, survey is required along the bankline of the observed eroded section, and extending some distance (i.e. 50 feet) into the river and some distance (i.e. 20 feet) beyond top of bank. Surveyed sections are required at sufficient frequency (i.e. every 50 feet) to provide an accurate model. While topography surveys such as LiDAR and bathymetry surveys are useful for most calculations, pole surveys more accurately capture the bankline slopes and erosion.

Sedimentation transects also exist for many section of the river. Some of these transects provide information from pre-inundation and within the past 20 years. Depending on the location of these transects, this information may be used to determine if the shoreline is migrating.

In the St. Paul District (MVP), erosion assessments, using the worksheet provided in table 4-2, can be completed in the field or by using maps or photographs.

The scoring method assists the PDT in determining if a site requires shoreline stabilization.

Table 4-2. Erosion Stabilization Assessment Worksheet – Shoreline or River Bank Reach

Factor	Criteria	Score	1	2	3	4	5	6	7	8	9	10
River Currents	0 to 1 fps	0										
	1 to 3 fps	5										
	> 3 fps	10										
Wind Fetch	0 to 0.5 miles	0										
	0.5 to 1 mile	5										
	> 1 mile	10										
Navigation Effects	Minimal	0										
	Surface Waves	5										
	Tow Prop-Wash	20										
Ice Action	No Ice Action	0										
	Possible Ice Action	5										
	Observed Bank Displacement	10										
Shoreline Geometry	Perpendicular to wind axis	0										
	Skewed to wind axis	2										
	Convex shape	5										
Nearshore Depths	0 to 3 feet	0										
	> 3 feet	3										
Nearshore Vegetation	Persistent, Emerged	0										
	Emergents	1										
	Submerged or no vegetation	3										
Bank Conditions	Hard Clay, Gravels, Cobbles	0										
	Dense Vegetation	1										
	Sparse Vegetation	2										
	Sand & Silt	3										
Local Sediment Source	Upstream Sand Source	0										
	No Upstream Sand Source	1										
		Total										

Total Score >18 - Bank Stabilization Needed; Total Score = 12 to 18 - Further Analysis Needed; Total Score < 12 - Bank Stabilization Not Needed

Upstream Reach Descriptions

Reach 1 -

Reach 2 -

Downstream Reach Description

Reach 4 -

Reach 5 -

2. Shoreline Stabilization Technique Selection. Once a site has been identified, the type of shoreline stabilization needs to be determined. There is significant variation from project to project depending on site conditions and project objectives. Additionally, river characteristics vary greatly between the districts. As a result, the approach to shoreline stabilization differs between the MVP and the Rock Island District (MVR). In the MVP, a typical distribution used is 20 percent riprap, 40 percent bio-geo, and 40 percent vegetative. More recent island projects in the MVP tend to have less riprap and use more bio-geo and vegetative stabilization. The MVR tends to use more rock. On existing shorelines, riprap and off-shore mounds are used more often than groins or vanes because one of the objectives for stabilizing an existing shoreline is usually to immediately stop erosion. Since groins and vanes allow some continued re-shaping of the shoreline, they are not often used. Table 4- 3 includes examples of various types of shoreline stabilization used on islands that have been constructed and table 4- 4 presents some general guidance for technique selection.

Table 4-3. Example Shoreline Stabilization Technique Distribution

		Riprap Stabilization Length		**Bio-Geo Stabilization Length**		**Vegetative Stabilization Length**		
Island	**Total Shoreline Length**	**(feet)**	**(%)**	**(feet)**	**(%)**	**(feet)**	**(%)**	**Year**
Weaver Bottoms		2,180	13	5,670	33	9,550	55	1986
Pool 8, Phase II Slingshot I	10,800 ft	600	6	7,520	70	2,680	*25*	1999
Polander Lake, Stage 2 Interior Islands	4,210 ft	120	3	0	0	4,090	97	2000
Long Island (Gardner) Div.	3,765 ft	3,765	100	0	0	0	0	2001
Spring Lake Islands, Island 3	74,000 ft	600	1	44,500	60	2,890	39	2006
Pool 11 Islands Sunfish Lake	4,921 ft	4,921	100					2002
Pool 11 Islands Mud Lake	3,477 ft	3,477	100					2004
Spring Lake	Perimeter Levee		100					1990s

Table 4-4. General Guidance for Stabilization Technique Selection

	Design Considerations							**Habitat Considerations**		
Feature	New Construction	Existing Shoreline	Water Depth < 3 ft	3 ft < Water Depth < 5 ft	Water Depth > 5 ft	Shoreline subject to wave action & littoral drift	Shoreline adjacent to moving current	Provide floodplain habitat & sand for beach formation	Provide habitat and elevation diversity	Provide protected deep waters
Rock Revetment	x	x	x	x	x	x	x			
Rock Groin	x	x	x	x		x				
Rock Vane	x	x	x	x	x		x		x	x
Off shore Rock	x	x	x	x		x	x		x	
Sand Berm	x	x	x	x		x	x	x	x	
Vegetation	x		x			x	x		x	
Large Woody Debris	x		x	x	x	x	x		x	

3. Cost. Shoreline stabilization costs include earth fill (granular and fines) for the berm, rock, and the cost of willow plantings. Figure 4-1 shows estimated costs, based on data collected by the MVP, for constructing various types of rock based shoreline stabilization in water depths of 1 to 6 feet. Based on this information, groins and vanes are the cheapest rock based stabilization option, regardless of water depth. Rock mounds are the most expensive option in all cases.

As is shown in table 4-5, vegetative solutions are the most cost effective method of shoreline stabilization. However, very few eroded sites can rely solely on vegetation for bank stabilization.

Table 4-5. Cost of Willow Plantings on Two Island Projects

Project	Bid Price	Shoreline Length	Cost per Foot	Year
Pool 8, Phase III, Stage 3B	$27,000	10,940	$2.47	2009
Pool 9, Capoli, Stage 1	$53,081	16,070	$3.30	2011

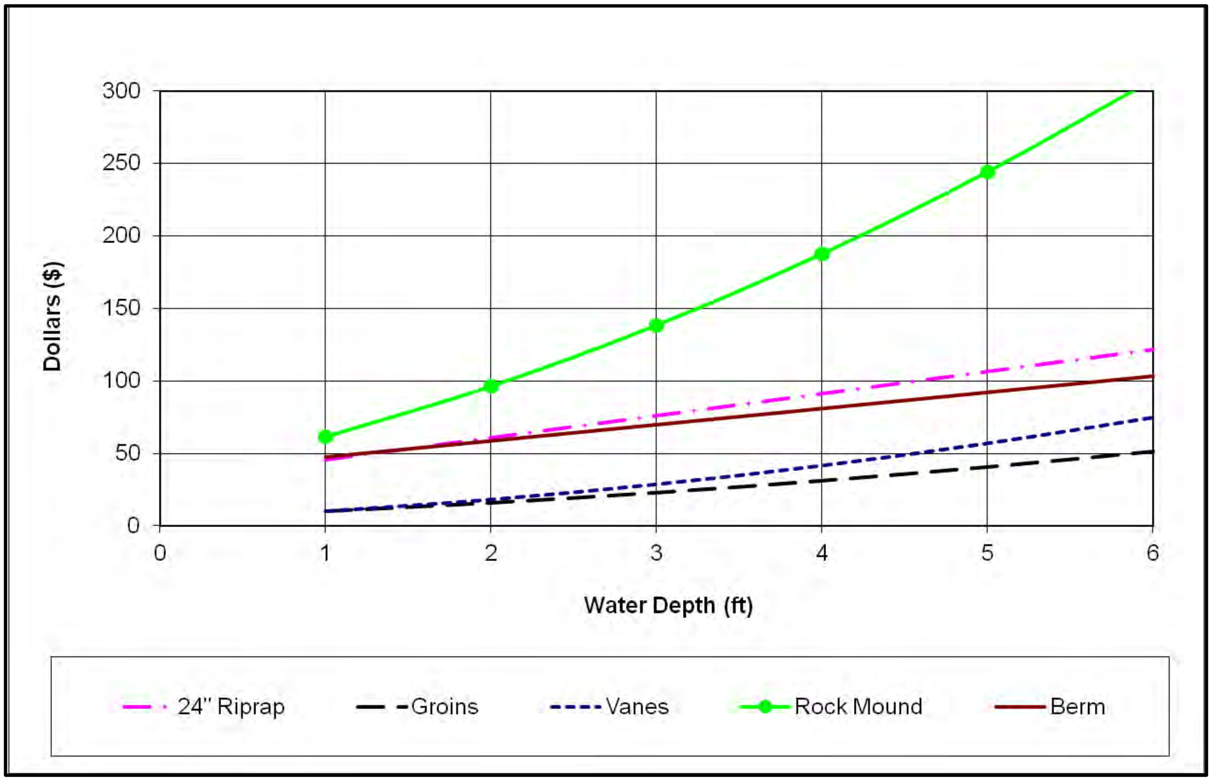


Figure 4-1. Rock-based Shoreline Stabilization Costs per Foot of Shoreline
(MVP Cost Data Based on 2011 Cost Estimates From *The Capoli Slough HREP*)

The cost data presented in the previous paragraphs, approximated from MVP data, assists in determining the relative cost effectiveness of the different types of bank stabilization. However, it is important to note that true cost will vary significantly depending on the location of the project. Additionally, rock costs will vary depending on the gradation selected, the location of the nearest USACE approved quarry, and the ability to transport the material to the site.

C. SHORELINE STABILIZATION TECHNIQUE DESIGN DETAILS

1. Rock Revetments. Placement of a rock revetment is shown in photographs 4-8, 4-9 and 4-10. Generally, two types of rock revetments are used:

Revetment 1 (Graded Riprap, 18 inches thick, 1V:2.5 to 3H side slope, with geotextile fabric) can be used on new construction such as islands or dikes.

Revetment 2 (Rock fill, 24 - 36 inches thick, 1V:1.5 to 3H side slope, no filter) can be used on new construction or existing shorelines which have variable slopes. The greater thickness of revetment 2 prevents piping of bank material, so no filter is required. As EMP designs have evolved, the thickness of revetment 2 has migrated from 36 inches to 24 inches. Based on observations of existing revetments in the MVP, a 24-inch thickness is sufficient. Typical design ranges are presented in table 4-6 and a profile detail is shown in figure 4-2. If the area will be subjected to ice action, the side slopes should be flattened to at least 1V: 4H.

Photograph 4-8. Long Island Bankline Prior to Rock Placement

Photograph 4-9. Placement of Rock Revetment at Long Island

Photograph 4-10. Area of Rock Placement at Long Island 8 Years Post Construction

Table 4-6. Typical Rock Revetment Design Criteria

Rock Slope	Thickness With Geotextile	Thickness W/out Geotextile	Height Above Normal Pool
1V:1.5H – 3H	18 inches	24 – 36 inches	1 – 5 feet

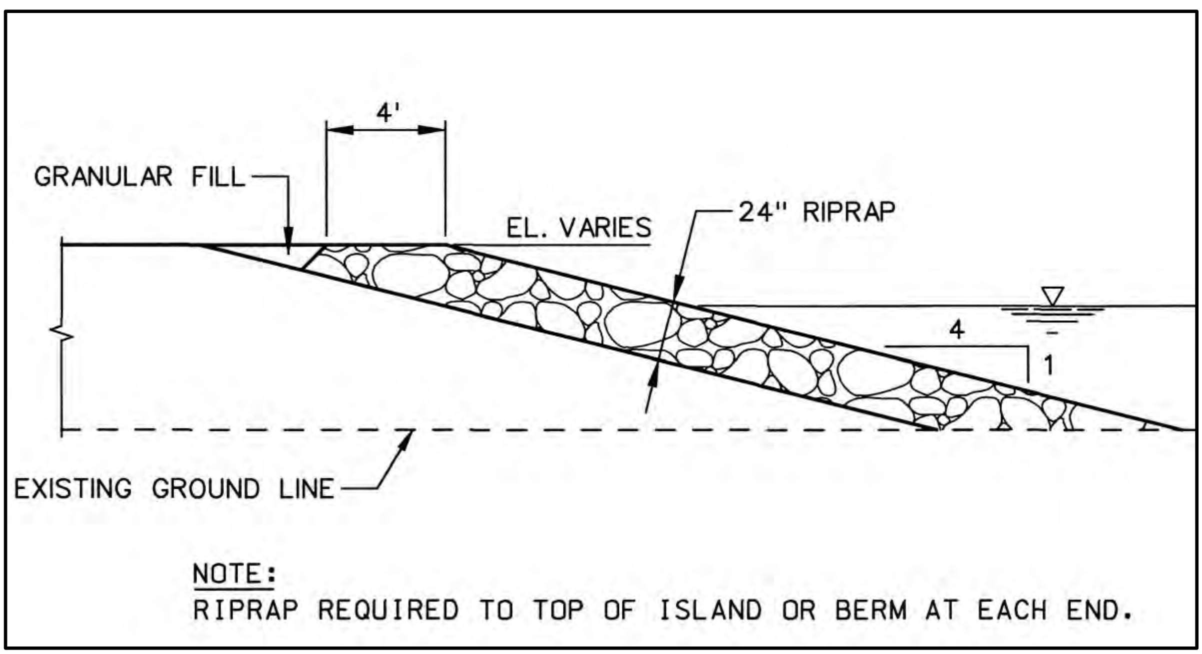


Figure 4-2. Rock Revetment Design Detail

CASE STUDIES AND LESSONS LEARNED

CASE STUDY 1. Rock Revetment - Lake Onalaska, Mississippi River Pool 7
Year Constructed - 1989

Rock Slope	Thickness	Height Above Normal Pool	10-yr Flood Height	Geotextile (ft)	Length
1V:3H	18 inches	5.0 feet	4.0 feet	Yes	7,370 feet

Lessons Learned: Portions of the 18” layer of rock (w filter fabric) placed at a 1V:3H slope were severely damaged by ice action during winter freeze-thaw expansion and spring break up. Subsequent maintenance involved placing additional rock over the damaged rock at a 1V: 4H slope. This has also been damaged by ice; however the rock thickness is adequate to prevent exposure of the underlying granular material.

Geotextile filter fabric placed on a 1V:3H slope was easy to install and resulted in an adequate filter.

CASE STUDY 2. Rock Revetment - Polander Lake, Stage I, Mississippi River Pool 5A
Year Constructed - 2000

Rock Slope	Thickness	Height Above Normal Pool	10-yr Flood Height	Geotextile (ft)	Length
1V:1.5 1V:3H	32	3.0 - 5.0 feet	8.5 feet	No	1,120 feet

Lesson Learned: The 32” layer of rock (without filter fabric place at slopes varying from 1V:1.5H to 1V:3H has been stable.

CASE STUDY 3. Rock Revetment - Pool 8, Mississippi River Phase I
Year Constructed - 2000

	Rock Slope	Thickness	Height Above Normal Pool	10-yr Flood Height	Geotextile (ft)	Length
Boomerang	1V:3H	18/27 inches	4.5 feet	4.5 feet	Yes	
Grassy	1V:3H	18/27 inches	2.5 feet	4.5 feet	Yes	780 feet
Horseshoe	1V:3H	18/27 inches	4.5 feet	4.5 feet	Yes	

Lessons Learned: The 18” layer of rock (w filter fabric) placed at a 1V:3H slope has been stable.

Waiting a year before designing the riprap allowed the Project Delivery Team to pinpoint erosion locations exactly. This resulted in a minimal amount of rock being needed along the outer edge of this island.

2. Rock Groins. Rock groins, shown in Photographs 4-11 and 4-12, are used mainly on new construction in shallow water where wave action and littoral drift are the dominant processes. Groins are placed perpendicular to the shoreline. After groins are constructed, shoreline reshaping occurs with deposition occurring near the groins and erosion occurring in the reach between two groins. This continues until a stable scalloped shape is formed. The erosion that occurs is usually acceptable for new construction, but is not acceptable on natural shorelines. The advantage of groins is cost savings (if in shallow water), creation of littoral and beach habitat, and an aesthetically pleasing shoreline.

Photograph 4-11. Newly Constructed Rock Groin in Pool 8

Photograph 4-12. Constructed Rock Groin in Pool 8 After a Few Years of Vegetation Growth)

The ratio of groin spacing to groin length varies from 4 to 6 for habitat projects. The height of rock groins varies from 1.5 to 2 feet above the average water surface. Table 4-7 shows typical design criteria and figure 4-3 shows an example design detail from Spring Lake Islands.

Table 4-7. Typical Rock Groin Design Criteria

Top Width	2 – 5 feet
Rock Slope	1V:1.5H – 2H
Height Above Average Water Surface Elevation	1.5 – 2 feet
Groin Length	30 – 40 feet
Groin Spacing	120 – 240 feet
Ratio of Groin Spacing to Groin Length	4 – 6 feet
Key-in	5 – 10 feet

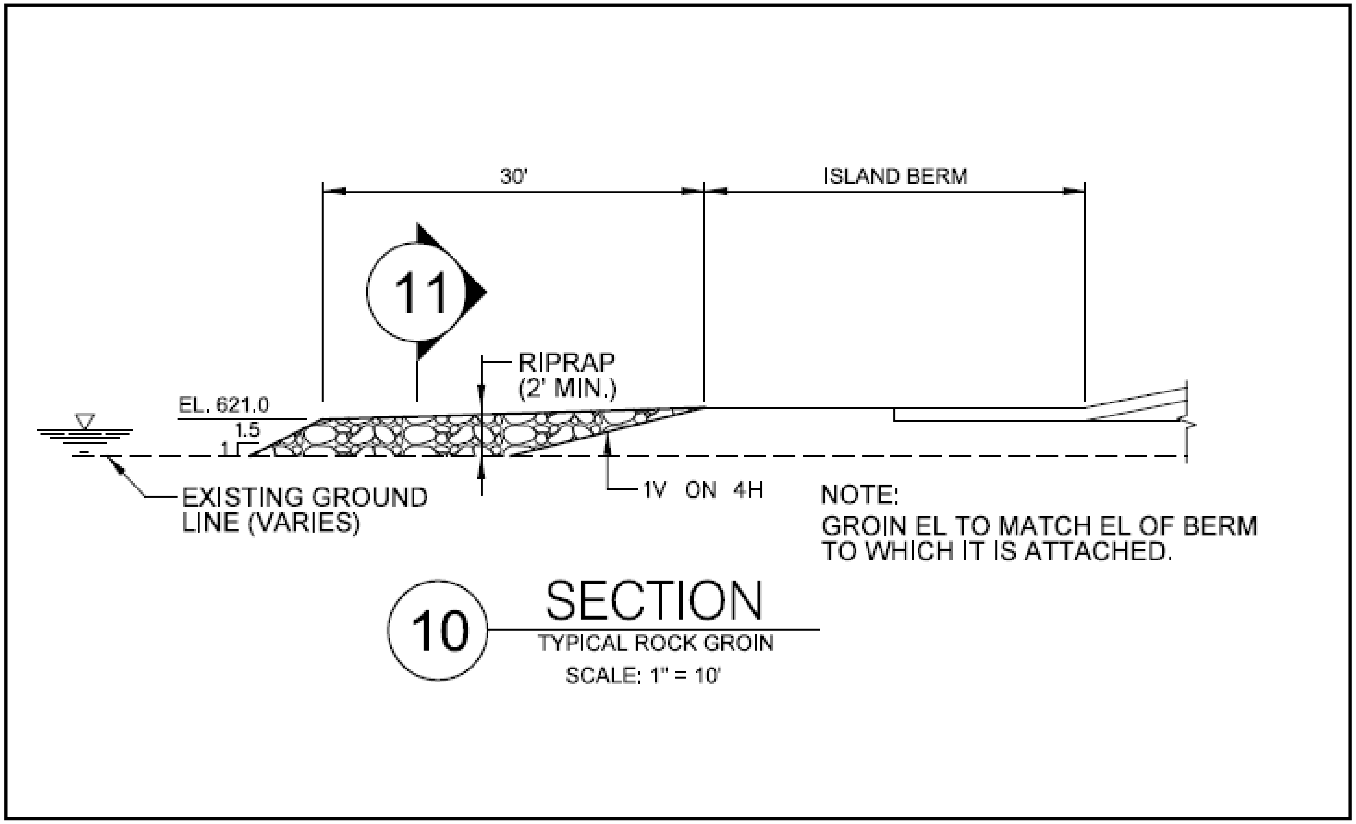


Figure 4-3. Rock Groin Design Detail

CASE STUDIES AND LESSONS LEARNED

CASE STUDY 4. Rock Groins - Weaver Bottoms, Mississippi River, Pool 5
Year Constructed - 1986

	Top Width	Rock Slope	Height Above Normal Pool	Groin Length	Groin Spacing	Length
Mallard Island	3 feet	1V:1.5H	1.5 feet	30 feet	150 feet	~5,600 feet
				30 feet	150 – 270 feet	
Swan Island	3 feet	1V:1.5H	1.5 feet	45 feet	180 feet	

Lessons Learned: Rock groins were built several years after the islands were constructed. These have stabilized the shorelines of Mallard and Swan Is. Some ice damage has occurred to the groins on Swan Is.

CASE STUDY 5. Rock Groins - Trempealeau National Wildlife Refuge, Mississippi River, Pool 6
Year Constructed – 1996/2003

Top Width	Rock Slope	Height Above Normal Pool	Groin Length	Groin Spacing	Length
3 feet	1V:1.5H	2 feet	30 feet	150 feet	7,600 feet

Lessons Learned: Severe ice damage displaced these groins, rendering them ineffective. These groins were re-built in 2003 using a flatter a 1V:5H end slope to cause ice to deflect up over the groins. So far this retro-fit seems to be working.

CASE STUDY 6. Rock Groins - Pool 8, Mississippi River Phase I
Year Constructed - 1992

Top Width	Rock Slope	Height Above Normal Pool	Groin Length	Groin Spacing	Length
2 feet	1V:2H	1.5 feet	30 feet	180 feet	~5,700 feet

Lessons Learned: The groins placed along these shorelines have effectively stabilized over a mile of shoreline.

3. Rock Vanes. As shown in photograph 4-13 and figures 4-4 and 4-5, rock vanes extend upstream from the shoreline and feature a sloping top elevation. As vanes are overtopped, they function as weirs and redirect flow away from the shore. Vanes are effective on shoreline adjacent to moving current

In many situations, vanes also function as groins by reducing littoral drift due to wind-driven wave action. Because of this dual function, the angle of the vane with the upstream shoreline is fairly large (45 to 60 degrees).

Vanes with angles ranging from 45 to 60 degrees have been constructed in an attempt to identify if there is an optimal angle for vanes on a large river system. In general, the vanes have not been in place long enough to draw a definitive conclusion. However, the vanes currently in place do seem to be performing well.

Currently, three types of vanes have been utilized: traditional, traditional with a root wad, and a J-Hook Style. Plan and profile views for a traditional vane are provided in figures 4-4 and 4-5.

Photograph 4-13. Rock Vanes at Lost Island Chute, Pool 5

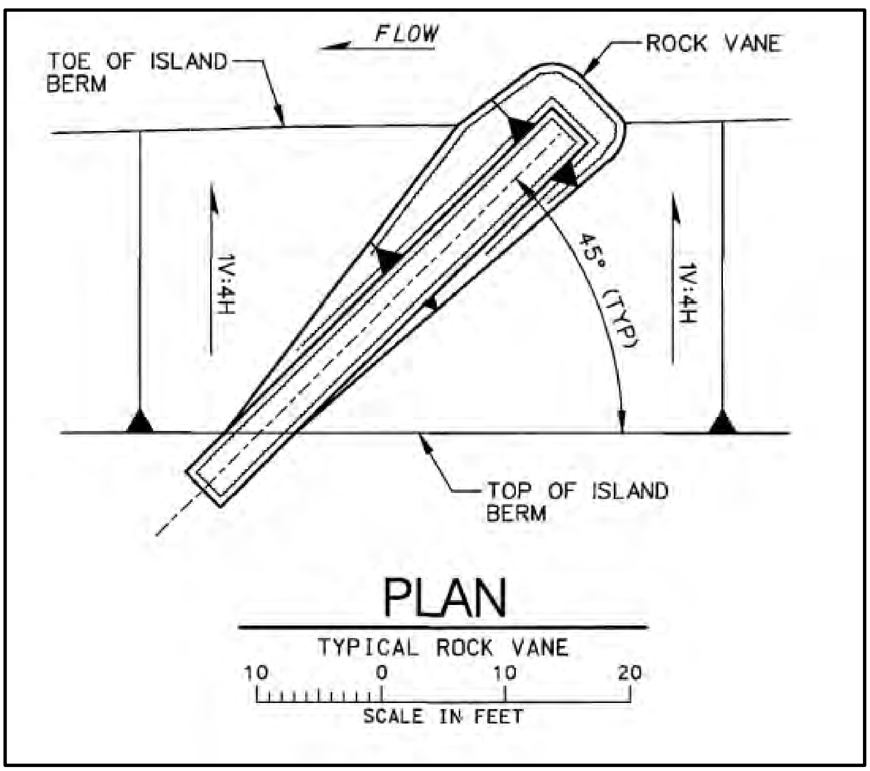


Figure 4-4. Plan View of a Vane Alignment

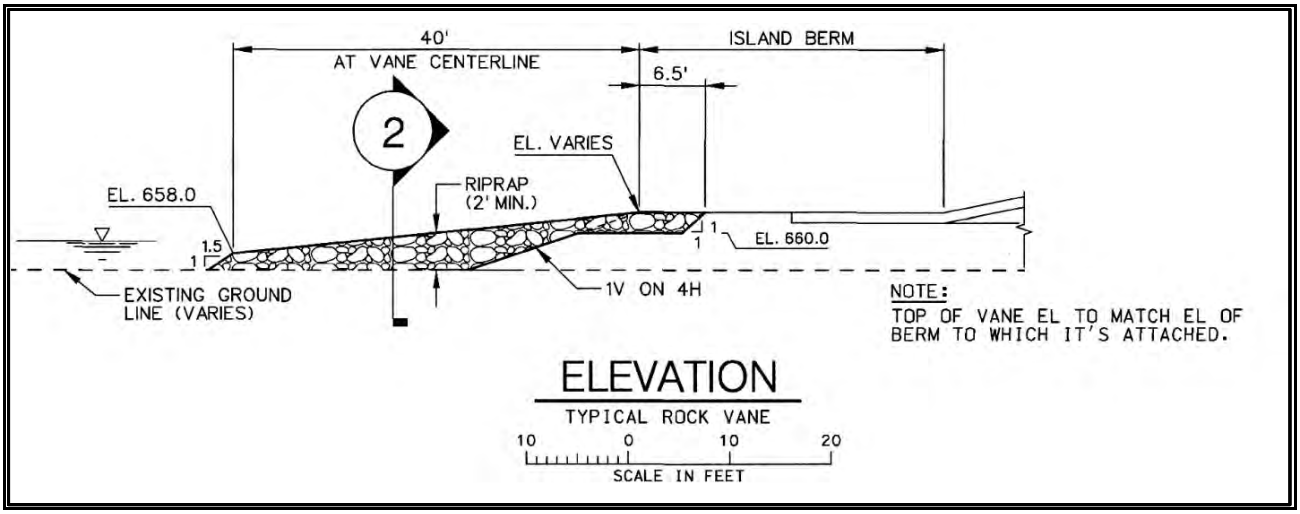


Figure 4-5. Typical Detail of a Rock Vane

The plan view of a J-Hook style vane is shown in figure 6 and photograph 4-14. While the application of J-Hook vanes has been successful in the MVP, applications further down river have encountered performance issues. The increased scour created by the hook of the J caused the structure to cave into itself. The J-hooks also require almost double the material of a rock vane while providing similar protection. These structures may be better served in a smaller stream.

Typical design criteria are presented in table 4-8.

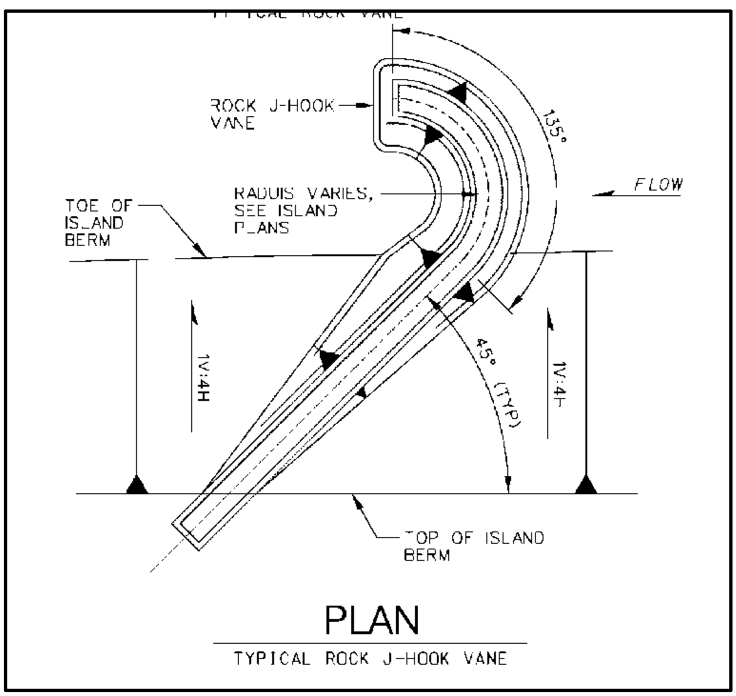


Figure 4-6. Plan View of a J-Hook Vane

Photograph 4-14. J-Hook Vane in Pool 8

Table 4-8. Typical Vane Design Criteria

Top Width	3 – 5 feet
Rock Slope	1V:1.5H – 3H
Height Above Average Water Surface Elevation	1.5 – 2 feet
Top Elevation Slope	10 – 12%
Length	30 – 45feet
Hook Length (J-Hook vanes only)	30 – 45
Angle (□)	40 – 55
Spacing Ratio (Length to Spacing)	1:3 - 4

CASE STUDIES AND LESSONS LEARNED

CASE STUDY 7. Rock Vanes - Lost Island Chute, Mississippi River Pool 5

Year Constructed – 2000

	Top Width	Rock Slope	Height Above Normal Pool	Groin Length	Groin Spacing	Angle	Length
Sec 1	3 feet	1V:1.5H	2 feet	30 feet	80 feet	45°	400 feet
Sec 2	3 feet	1V:1.5H	2 feet	30 feet	120 feet	45°	480 feet

Lessons Learned: The vanes appear to have stabilized the shoreline though some reshaping is still occurring. The 80-foot spacing could have been a little larger.

CASE STUDY 8. Rock Vanes - Spring Lake Islands, Mississippi River Pool 5

Year Constructed – 2006

	Top Width	Rock Slope	Height Above Normal Pool	Groin Length	Groin Spacing	Angle	Length
Island 4	4 feet	1V:1.5H	2 feet	30 feet	100 feet	45°	14,000 feet

Lessons Learned: The vanes on Island 4 were placed too close to the deep channel. The shoreline eroded farther than anticipated and almost cut behind the key-in. The PDT did not pursue remedial measures and even though this island has been overtopped twice since construction, the shoreline on island 4 has remained stable.

4. Offshore Rock Mounds. Offshore rock mounds, shown in photograph 4-15 and figure 4-7, are used on natural shorelines in four situations:

1. shorelines with shallow nearshore bathymetry which prevents access by marine plant
2. low shorelines or marsh area where there is not a well defined shoreline (i.e. river bank) to place revetment on or tie groins or vanes into
3. shorelines with shallow nearshore bathymetry where it is desirable to get the outside toe of the rock into deeper water to prevent undercutting
4. shorelines with heavy wood debris that would prevent the direct placement of rock

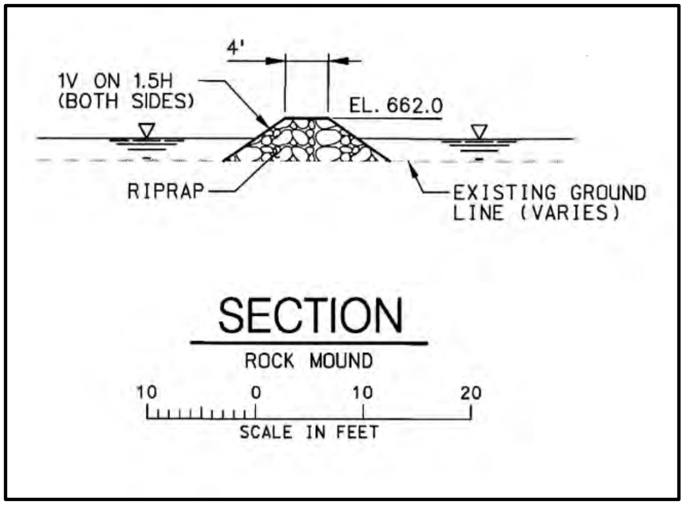


Figure 4-7. Offshore Rock Mound Design Detail.

Photograph 4-15. Offshore Rock Mound at Peterson Lake in Pool 4

Design criteria for offshore rock rounds are presented in table 9.

Table 4-9. Typical Offshore Rock Mound Design Criteria

Top Width	3 – 5 feet
Rock Slope	1V:1.5H – 3H
Height Above Average Water Surface Elevation	1.5 – 2 feet

CASE STUDIES AND LESSONS LEARNED

CASE STUDY 9. Offshore Rock Mound - Weaver Bottoms, Mississippi River Pool 5
Year Constructed - 1986

	Rock Back Slope	Rock Front Slope	Height Above Normal Pool	10-yr Flood Height	Top Width	Length
Swan Island	1V:1.5H	1V:1.5H	3.0 feet	4.0 feet	3.0 feet	800 feet

Lessons Learned: Offshore rock mounds will decrease in elevation with time due to substrate displacement, ice action, toe scour, or some combination of factors. This happened on the north side of Swan Island, and resulted in a decrease in mound elevation of at least 1 foot during the first 5 years of the project. Because the rock mound had been constructed fairly high initially, it continued to reduce wave action at the toe of the island.

Construction access to various shoreline reaches was a significant and contentious issue during plans and specs development. Requiring marine access would have entailed significant amounts of dredging. However gaining access by traveling on top of the island would have destroyed terrestrial vegetation.

CASE STUDY 10. Offshore Rock Mound - Polander Lake, Mississippi River Pool 5A
Year Constructed - 2000

Rock Back Slope	Rock Front Slope	Height Above Normal Pool	10-yr Flood Height	Top Width	Length
1V:1.5H	1V:3H	4.5	8.5	3.0	600 feet

Lessons Learned: An offshore rock mound was constructed to act as breakwater to prevent wave action from impacting a portion of the backwater. The rock mound has been stable.

5. Rock-Log Structures. In protected areas with minimal ice impacts, rock-log structures provide an economical alternative to offshore rock mounds. These structures protect existing shoreline while providing woody structure for fish and loafing areas for wildlife. Photographs 4-16 and 4-17 show a typical rock-log structure application.

Photograph 4-16. Installation of a Rock log Structure

Photograph 4-17. Rock-log Structure in Place

The minimum rock cover required to anchor the logs in place is provided in table 4-10.

Table 4-10. Typical Rock-log Structure Design Guidance

Top Elevation	Varies
Minimum Rock Cover if 15' of Tree is Covered	2 feet
Minimum Rock Cover if 20' of Tree is Covered	1.5 feet
Minimum Length of Rock Cover with Geogrid	5 feet
Rock Slope	1V:2H
Height of Tree Trunk Above the Bottom	2 – 2.5 feet

CASE STUDIES AND LESSONS LEARNED

CASE STUDY 11. Rock-Log Structure - Rosebud Island, Mississippi River Pool 7
Year Constructed - 2001

Rock Back Slope	Rock Front Slope	Height Above Normal Pool	Rock Top Width	Length
1V:2H	1V:2H	2 feet	3 feet	140 feet

Lessons Learned: After the initial design was done, a design was developed that involved the use of a geo-grid placed over the logs, with rocks subsequently placed on the geo-grid. This reduced the length that each log had to be covered to 5 feet. The geo-grid has worked well. Using two logs instead of three would have left some space for water to flow under the logs.

6. Berms and Vegetation

a. Design Criteria. One of the primary purposes of the berm is to provide conditions for the growth of woody vegetation, which reduces wave action on the main part of the project feature (e.g. island or dike) during floods. Although colonization by woody plants will occur naturally, sandbar willow (*salix exigua*) is usually planted on berms to increase the rate of colonization. Within a few years, the willows usually spread to cover 20 or 30 feet of the berm and side slopes. Other species such as False Indigo and Willow hybrids have been used in smaller quantities.

Photograph 4-18. Pool 5, Weaver Bottoms, Swan Island.
Native prairie grasses were planted to provide nesting habitat and stabilize the top of the island.

Table 4-11. Berm Design Criteria

Top Width	20 – 50 feet
Slope	1V:4H – 5H
Height Above Normal Water Surface Elevation	2.5– 3 feet

CASE STUDIES AND LESSONS LEARNED

CASE STUDY 12. Berms – Boomerang Island, Phase I, Mississippi River Pool 8
Year Constructed - 1992

Waterline to Transition Slope	Transition to Top of Island Slope	Height Above Normal Pool	Top Width	Length
1V:20H & 1V:13H	1V:5H	4 feet	45 feet	~3miles

Lessons Learned: Constructing low berms results in rapid colonization by woody vegetation, increasing island stability during floods. Over three miles of shoreline were stabilized using berms, groins, and vegetation. Within a few years willow growth on the berm spreads from the water line to almost the top of the island, providing a 20- to 30-foot swath of willows.

b. Large Woody Debris. Islands and associated shoreline stabilization structures provide loafing habitat for many species. The Fish and Wildlife Work Group established the following parameters for using large woody debris:

The main trunk of the tree should be a minimum of 25 feet long and gently sloped so that with changing water levels there are loafing areas available most of the time. A mixture of elevations is best, due to the different preferences and capabilities of different species. Generally, these structures should be placed in areas sheltered from wind generated waves. These structures can be placed in sand or anchored into the shoreline with a rock key-in. Example design details of large woody debris are shown in figures 4-8 and 4-9.

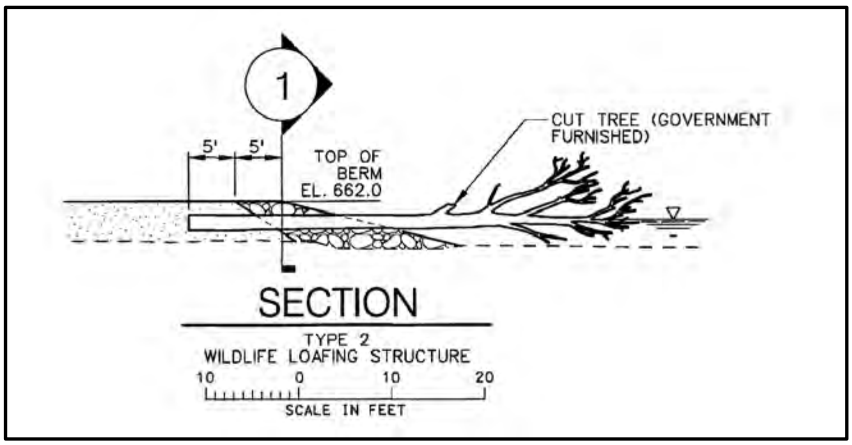


Figure 4-8. Design Detail of Large Woody Debris

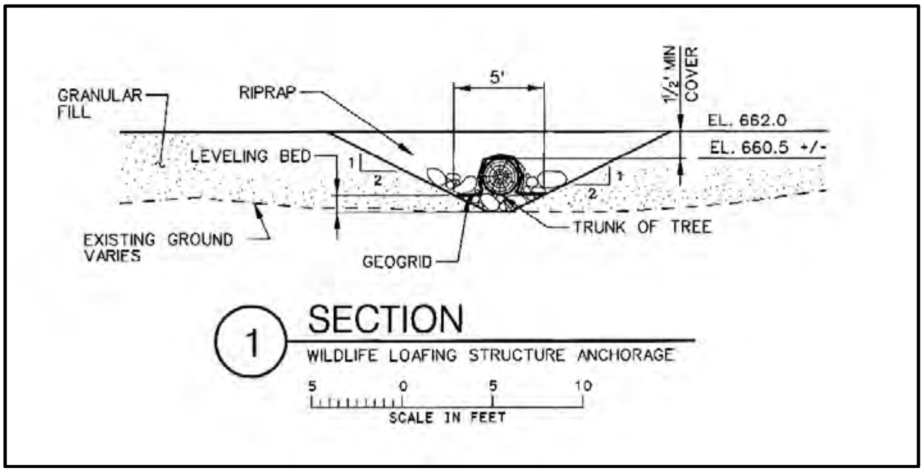


Figure 4-9. Design Detail of Large Woody Debris Anchorage

Table 4-12. Typical Large Woody Debris Design Criteria

Height Above Summer Pool	2 – 12 inches
Length of Tree	> 25 feet
Diameter of Tree	10 – 24 inches
Preferred Species	Black Locust/White Oak
Location	Sheltered Backwaters/Secondary Channels
Number	Multiple Trees May Be Used In One Application

CASE STUDIES AND LESSONS LEARNED

CASE STUDY 13. Large Woody Debris - Spring Lake Islands, Mississippi River Pool 5
Year Constructed - 2006

	Berm Key-in	Minimum Rock Cover	Height Above Normal Pool	Geogrid	Location
Island 2	10 feet	1.5 feet	0 – 0.5 feet	Yes	Mudflat

Lessons Learned: The Mississippi River distributes large woody debris during high water events. If the project location is likely a deposit area for large woody debris during high water events, including them as a project feature may not be necessary.

D. PLANS AND SPECIFICATIONS

1. Surveys. Surveys of the eroded area should be taken at set intervals starting at the top of bank and continuing to the point at which the bank slope flattens below the average water surface elevation. Lengths of eroded areas should also be surveyed.

2. Plans. Drawings should include a plan view of the site indicating the length of protection. Drawings should also include select survey transects, and a typical section. Drawings should show expected slopes, thickness of rock, and rock gradation size. A typical drawing is shown in figure 4-10.

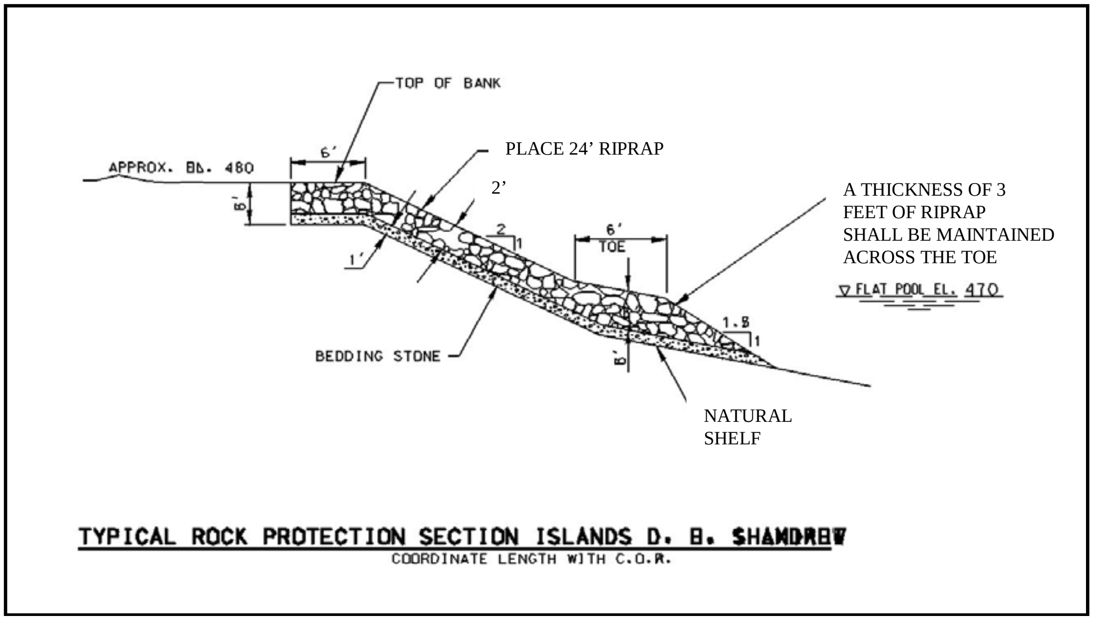


Figure 4-10. Typical Rock Protection Section

3. Quantities. As a general rule of thumb, once the cubic yards of material are estimated (through Micro station, Inroads, or simple geometry), the following equations can be used to estimate tons of material required:

Equation 2-1: Cubic Yards of Material * Y = Expected Rock Weight
where:
Y(MVP) = 1.45 tons/CY material
Y(MVR) = 1.65 tons/CY material,
Y(MVS) = 1.5 – 1.6 tons/CY material (for graded riprap),
Y(MVS) = 1.6 – 1.7 tons/CY material (for bedding material).

E. ROCK SIZING AND DESIGN CONSIDERATIONS

Basic guidance for shoreline stabilization rock sizing and riprap design is presented in EM 1110-2-1601 (EM 1601) and the Coastal Engineering Manual. Typically, Hydraulics will analyze required rock size and thickness for erosion due to flow and wave wash, and Geotech will establish the gradation and verify the thickness.

While it is important to ensure the riprap and rock sections resist the primary method of erosion, in general, EMP projects should incorporate more risk than Flood Control or Section 14 projects. Rock sizing and layer thickness determined by using either of these manuals should be considered the maximums for an EMP project. Project design teams should investigate opportunities to minimize rock size and thickness.

However, in some cases it may be desirable to have a larger rock gradation. Surveys done by the MVP (Niemi & Strauser, 1992) indicate that rock gradations that include larger rocks and subsequently larger voids improved habitat for fish. Another consideration, if near shore depths are relatively deep, might be incorporating woody structure into the design to provide fish cover.

1. Gradation and Thickness. Design criteria for rock gradation and thickness vary depending on the location of the project site. Each District has specific concerns and guidelines that need to be addressed. For this reason, gradation and thickness will be presented by district (St. Paul, Rock Island, and St. Louis).

2. St. Paul. Table 4-13 shows typical rock gradations used by MVP for riprap, vanes, and groins. The standard gradation, which is similar to ASTM R-60, was established based on ease of obtaining it from quarries and the requirements for wave action which is the primary erosive force affecting river shorelines. The large gradation has been used when wind fetch exceeded 2 miles, ice action was expected to be a problem, or a potential for vandalism (i.e. movement of rock by people) existed. The cobble gradation was used to repair sections of the Pool 8, Phase II islands that were damaged during the 2001 flood, and is being used to create mussel habitat at the Capoli Slough project. The river-washed stone gradation was used in the Pool 8, Phase III project and is being used to create mussel habitat at Capoli Slough. These sections were not exposed to significant wave action and field reconnaissance indicated that while sand size material had been eroded during overtopping, gravel-size material and larger was stable, so a cobble gradation was used.

Table 4-13. St. Paul District Rock Gradations Used on HREP Projects.

Limits of Stone Weight for Percent Lighter by Weight	Standard Gradation	Large Gradation	River Washed Stone	Cobbles
W100 Range (lbs)	300 to 100	630 to 200	25 to 6	16 to 8
W50 Range (lbs)	120 to 40	170 to 70	10 to 3	7 to 4
W15 Range (lbs)	25 to 8	60 to 15	5 to 0.5	3 to 1

Layer thickness (T) should equal 1 times $D_{100,max}$ or 1.5 times $D_{50,max}$, whichever results in the greater thickness.

3. Rock Island. MVR designs rock protection in accordance with EM 1110-2-1614 *Design of Coastal Revetments, Seawalls, and Bulkheads*.

4. St. Louis. Stone gradations used for MVS HREP projects are primarily graded riprap called graded stone “B” and “C”. Depending upon specific site design considerations, bedding material and/or geotextile will be used in the design section. Gradations and standard thickness for these materials are presented in table 4-14, 4-15, and 4-16.

Table 4-14. St. Louis District Bedding Material Gradation[1]

U.S. Standard Sieve	Percent by Weight Passing
3 inch	90 – 100
1.5 inch	35 – 70
No. 4	0 – 5

[1] Standard Bedding Material thickness ranges from 8 to 12 inches.

Table 4-15. St. Louis District Graded Stone B Gradation[1]

Limits of Stone Weight, lbs, for Percent Lighter by Weight	Stone Weight
100 (lbs)	1200 lbs
72 – 100 (lbs)	750 lbs
40 – 65 (lbs)	200 lbs
20 – 38 (lbs)	50 lbs
5 – 22 (lbs)	10 lbs
0 – 15 (lbs)	5 lbs
0 – 5 (lbs)	<5 lbs

[1] Standard thickness for the Graded Stone B gradation ranges from 30 – 42 inches.

Table 4-16. St. Louis District Graded Stone C[1] Gradation.[2]

Limits of Stone Weight, lbs, for Percent Lighter by Weight	Stone Weight
100 (lbs)	400
70 – 100 (lbs)	250
50 – 80 (lbs)	100
32 – 58 (lbs)	30
15 – 34 (lbs)	5
2 – 20 (lbs)	1
0 – 5 (lbs)	<5

[1] Standard thickness for the Graded Stone C gradation ranges from 18 to 24 inches.
[2] 5% of the material can weigh more than 400 lbs. No piece shall weigh more than 500 lbs.

Additional design considerations for shoreline stabilization techniques involving the use of rock are provided in table 4-17.

Table 4-17. Other Design Considerations for Rock

Design Consideration	General Guidance for EMP Designs
Toe Protection	"When designing a riprap section to stabilize a streambank, the designer accounts for scour in one of two ways: 1) by excavation to the maximum scour depth and placing the stone section to this elevation, or 2) by increasing the volume of material in the toe section to provide a launching apron that will fill and armor the scour hole. Preference should usually be given to option (2) because of ease of construction and lower cost, and because of environmental impacts associated with excavation of the streambed." (ERDC/EL TR-03-4) • Typically, the toe extends 6 feet once the slope flattens.
Filter or Bedding	Filter or bedding should be used if soil movement through the riprap is a concern. Guidance for filter design is provided in EM 1110-2-1901, Appendix D. • Filter fabric may be eliminated if thickness of riprap layer is doubled.
Side Slopes	Based on guidance provided in EM 1601, riprap section side slopes should not be steeper than 1V on 1.5H. • 1V on 2 - 3H is preferred.
Shoreline Key-in	• A key-in to the existing shoreline of 5 – 10 feet is recommended for riprap stabilization.
Field Stone	When rounded stone is used instead of angular stone, the D_{50} calculated for angular stone should be increased by 25%.
Wave Action Prop Wash	If the riprap section will need to withstand the forces created by the prop of a tow, riprap size should be determined by using the guidance provided in "Bottom Shear Stress from Propeller Jets" (Maynord).
Ice Action	• Rock slopes should be 1V:4H or flatter • Maximum rock size should be increased to 2*ice thickness (Sodhi).
Underwater Placement	• When riprap is placed underwater, the layer thickness should be increased by 50 percent, but the total thickness should not be increased by more than 12 – 18 inches. • If the depth of water is less than 3-4 feet and good quality control can be achieved, a 25% increase in layer thickness is adequate.
Construction Accessibility	Many sites requiring stone may be located in remote, shallow areas. Access to the site must be available for truck or barge. If access to the site is being achieved by land routes, consideration should be given to the viability of the existing access roads. This should include, but is not limited to, load limits, disruption of typical traffic patterns, and coordination with local officials. Additionally, sufficient water depth may require dredging before stone can be placed, and trees may need to be removed before the bankline is cut back or rock is placed.
Construction Techniques	Placement of smaller stone in a fast moving current could cause a significant loss of stone. Ensure that stone is sized in accordance with the conditions in which it will be placed.
High Turbulence Conditions	If the area being protected is subject to high turbulence, plate 29 from EM 1601 (v.1970) should be used for rock sizing and design.

F. REFERENCES

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Collins, M. J., and J. C. Knox, 2003. Historical Changes in Upper Mississippi River Water Areas and Islands. Journal of the American Water Resources Association. Paper No. 01221

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Sodhi, D.S., S.L. Borland, and J. M. Stanley, C. J. Donnelly. 1997. Ice effects on riprap: Small-scale tests. In Energy and Water: Sustainable Development, 27th International Association for Hydraulic Research Congress, San Francisco, pp. 162-167

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EM 1110-2-1614, *Design of Coastal Revetments, Seawalls, and Bulkheads*, June 1995

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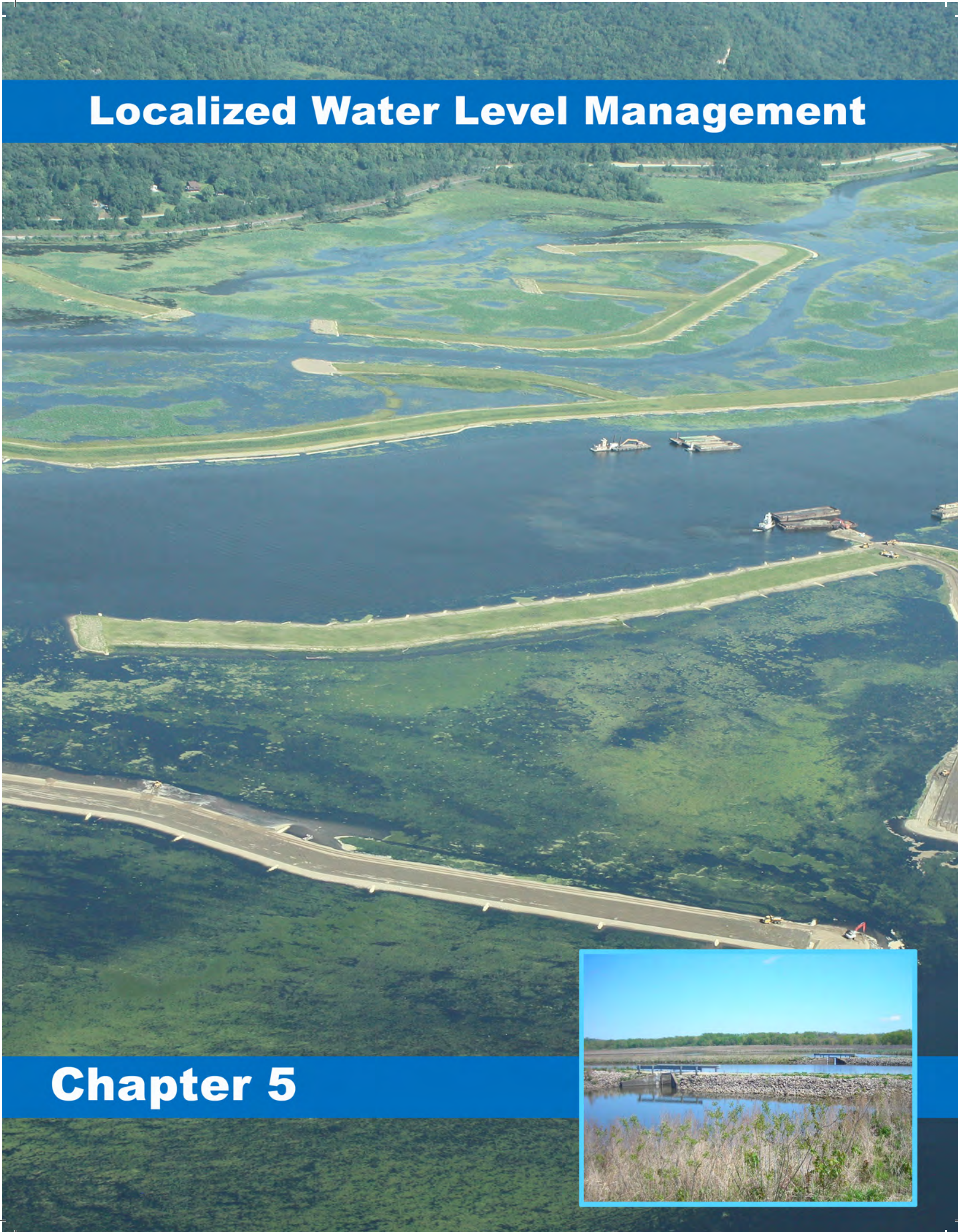
Localized Water Level Management

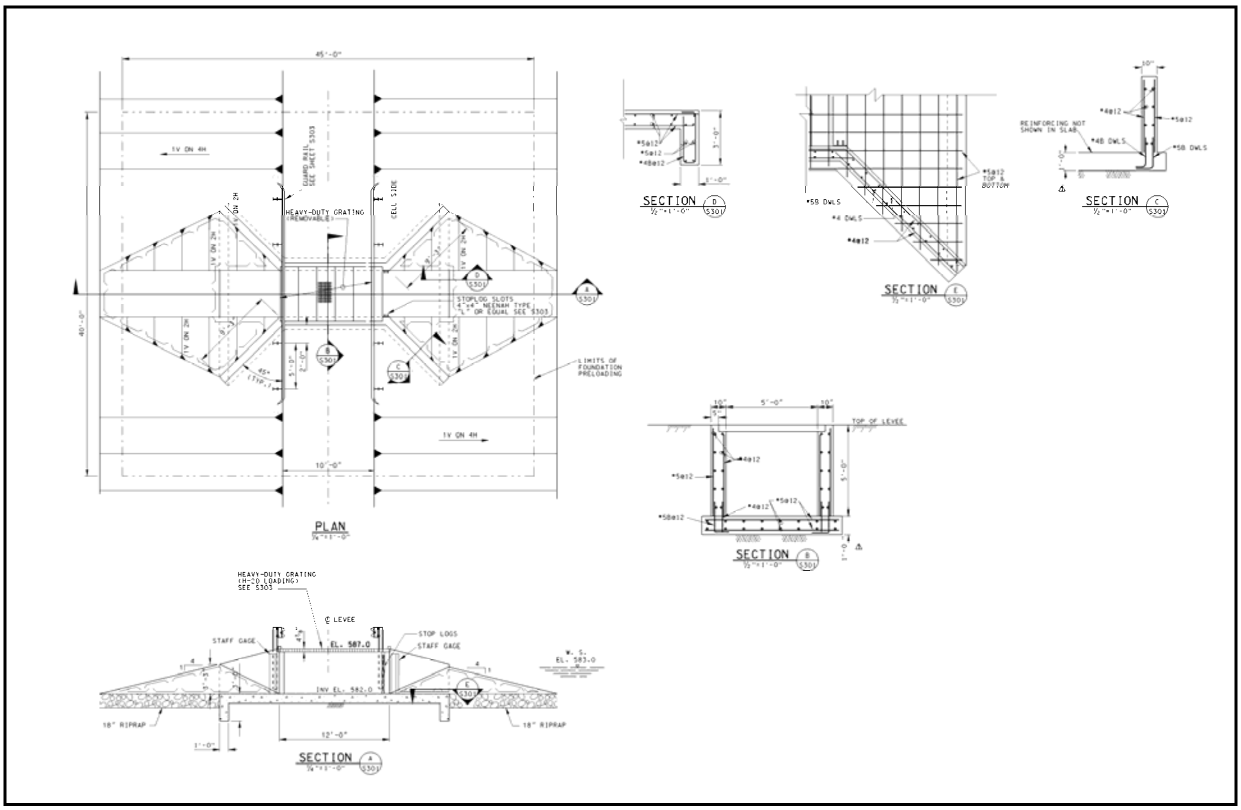


Chapter 5

UPPER MISSISSIPPI RIVER RESTORATION
ENVIRONMENTAL MANAGEMENT PROGRAM
ENVIRONMENTAL DESIGN HANDBOOK

CHAPTER 5

LOCALIZED WATER LEVEL MANAGEMENT



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UPPER MISSISSIPPI RIVER RESTORATION
ENVIRONMENTAL MANAGEMENT PROGRAM
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CHAPTER 5

LOCALIZED WATER LEVEL MANAGEMENT

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PHOTOGRAPHS

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CHAPTER 5

LOCALIZED WATER LEVEL MANAGEMENT

A. RESOURCE PROBLEM AND OPPORTUNITIES

1. Pre-Inundation Conditions. Large river ecosystems such as the Upper Mississippi River System (UMRS) are characterized by seasonal cycles of flood and drought (or low flow). A variety of ecological functions and processes are linked to this cycle. Development of water resources for hydropower or navigation typically alters and disrupts these natural cycles. Fortunately in the UMRS, the flood stage of the hydrograph is relatively unaltered, but low stages have been eliminated to support commercial navigation.

2. Resource Problems. Much of the flora and fauna native to the Upper Mississippi River (UMR) region is adapted to the wide variations in water level that characterized the river and its floodplain prior to establishment of the lock and dam system. Since the implementation of the 9-Foot Channel Project, however, these variations have been truncated and the low river stage portion of the hydrograph has been increased to support commercial navigation. This water level control, coupled with other cumulative effects, has degraded ecosystem conditions, mainly the loss of backwater depth and aquatic plants in many areas.

3. Resource Opportunities. Numerous (27 as of 2005) Environmental Management Program (EMP) habitat projects have attempted to recreate this variability in specific areas to benefit such species. Several responses to water level management projects have been demonstrated since the 1997 Report to Congress. For example, Lake Chautauqua on the Illinois River near Havana, Illinois has been managed as a National Wildlife Refuge (NWR) since 1936, but wetland management capabilities and habitat quality had degraded over the years. Improved water level management capabilities in the southern pool completed in 1999 resulted in phenomenal wetland plant response, which, in turn, was met with the highest waterfowl use since the 1970s. Submersed aquatic vegetation and marsh plants colonized almost 1,400 acres after project completion. Fish response monitoring indicates the site can produce and export hundreds of millions of larval fish to the Illinois River.

B. HABITAT REHABILITATION AND ENHANCEMENT PROJECT (HREP) OBJECTIVES [1]

Recent evaluations of habitat objectives and opportunities through pool planning and the UMR-Illinois Waterway (IWW) Navigation Feasibility Study are revealing that water level management may be the only reliable mechanism in some instances to counteract the impacts of impoundment and floodplain development and thus achieve the desired habitat conditions. Evidence from EMP and other water level management projects indicates these projects can be effectively operated for multiple management objectives, including waterfowl, shorebirds, wading birds, reptiles, amphibians, and fisheries. However, water level management projects that include embankments, pumps, and control structures are more costly to build, maintain, and operate relative to other types of HREPs.

1. Hydraulics and Hydrology. Water level management is the direct manipulation of hydrology in a specific area with the purpose of eliciting a physical and biological response. Water level management is typically used on the river to restore the low-water portion of the natural seasonal hydrology, which was removed with the completion of the locks and dams. However, water level management strategies also include the active flooding of higher ground, as is the case with moist soil management techniques.

2. Geomorphology. Water level management can be used to influence geomorphology, though habitat and biological categories are more typically the focus. Water level management can be used to lower water levels to dry out and consolidate sediment. This can help stabilize sediment, reduce erosion and also counter the effects of past sedimentation. These effects can help meet bathymetric diversity objectives.

3. Biogeochemistry. Water level management can indirectly address biogeochemistry objectives through effects to vegetation. Lowering water levels during the growing season typically leads to a favorable response by aquatic and emergent vegetation, which can improve nutrient cycling and dissolved oxygen levels. Improved vegetation will also reduce sediment resuspension, leading to improved water quality.

4. Habitat. Water level management techniques are used to address habitat objectives by restoring hydrology to improve vegetation and/or the use of habitat by wildlife such as shorebirds and waterfowl. Drawdown in backwaters has been shown to help restore diverse and abundant native aquatic vegetation communities through the restoration of a more natural seasonal hydrograph. Moist soil management units (MSMU) can create important wetland habitat within the floodplain that serve waterfowl and shorebirds.

5. Biota. Water level management (and most features used in HREPs) indirectly affect biota through other effects to hydrology, geomorphology, biogeochemistry, and habitat. The effects to biota are seldom measurable in a manner that can clearly prove a cause and effect relationship with project features, so they are often assumed to correlate with physical habitat objectives.

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[1] For a detailed explanation of the overall EMP vision, goals, and objectives, see Chapter 2, *Habitat Rehabilitation and Enhancement Projects.*

C. TYPES OF WATER LEVEL MANAGEMENT

Water level management features are named differently depending on the type of habitat improvements and other considerations. For the purpose of this report, they are divided into two categories, MSMUs and backwater lakes. The features which can control water levels will apply regardless of which name is chosen for the habitat.

1. Moist Soil Management Units

a. General Overview. The basic operating plan for an MSMU is to keep water out in the late spring and summer and to gradually flood the area in the fall. In a multiple cell system, it is best to be able to control water levels independently. One way to accomplish this independent filling is to have the pump discharge into a water control structure along an interior berm. This structure would be designed to have structures at both ends to control flow to either cell. A gate structure would be installed within each cell to allow independent gravity drainage. Table 5-1 represents a typical annual management plan for an MSMU.

Table 5-1. Typical MSMU Annual Management Plan

Month	Action	Purpose
Jul to Sep	Maintain water levels to minimum extent possible	Expose and maintain mudflats to allow vegetation growth
Oct to Nov	Gradually increase water levels	Provide access to aquatic food plants for migratory waterfowl
Dec to Apr	Maintain water levels to maximum extent possible	Maintain winter furbearer habitat
May to Jun	Gradually decrease water levels	Prepare for aquatic plant germination

Moist Soil Management Units are typically designed to include water containment, water supply, and water control structures. Water containment is provided by construction of exterior berms, interior berms, and overflow spillways; which are used to impound water during seasonal waterfowl migrations or keep water out of the impounded area. Water supply may be provided by either river water or ground water through the use of a pump station or well, respectively. Water control structures are utilized to maintain desired water elevations throughout the year. There are many types of water control structures such as stoplog, gated, overflow weir, and fuse plug. The water control structures typically used for HREP projects include stoplog, gated or other measures.

Moist Soil Management Units are part of the HREPs listed here. The design features for MSMUs are described in Section D.

Andalusia Refuge HREP, Pool 16, UMR RM 462.0-463.0, Rock Island Co., IL, MVR
Batchtown HREP, Pool 25, UMR RM 242.5-246.0, Calhoun Co., IL, MVS
Bay Island HREP, Pool 22, UMR RM 311.0-312.0, Marion Co., MO, MVR
Calhoun Point HREP, Pool 26, UMR RM 221.0-221.0, Calhoun Co., IL, MVS
Clarksville Refuge HREP, Pool 24, UMR RM 275.0-275.0, Pike Co., MO, MVS
Dresser Island HREP, Pool 26, UMR RM 206.0-209.0, St. Charles Co., MO, MVS
Guttenberg Waterfowl Ponds HREP, Pool 11, UMR RM 614.0-615.0, Grant Co., WI, MVP
Pleasant Creek HREP, Pool 13, UMR RM 548.7-552.8, Jackson Co., IA, MVR
Pool Slough HREP, Pool 9, UMR RM 673.0-673.0, Allamakee Co., IA MVP
Potters Marsh HREP, Pool 13, UMR RM 522.5-526.0, Carroll Co. and Whiteside Co., IL, MVR
Princeton Refuge HREP, Pool 14, UMR RM 504.0-506.4, Scott Co., IA, MVR
Rice Lake HREP, LaGrange Pool, IWW RM 132.0-138.0, Fulton Co., IL, MVR
Spring Lake HREP, Pool 13, UMR RM 532.5-536.0, Carroll Co., IL, MVR
Stump Lake HREP, Alton Pool, IWW RM 7.2-12.7, Jersey Co., IL, MVS
Swan Lake HREP, Alton Pool, IWW RM 5.0-13.0, Calhoun Co., IL, MVS
Trempealeau NWR HREP, Pool 6, UMR RM 718.0-724.0, Trempealeau Co., WI, MVP

MVR – Rock Island District; MVS – St. Louis District; MVP – St. Paul District

b. Biota and Habitat Considerations. Generally, the goal of an MSMU is wetland habitat enhancement with the objective of providing suitable habitat for waterfowl. Moist Soil Management Units are typically managed to include annual draw-downs. This technique is well accepted for wetland management and has been considered necessary for rejuvenating older, unproductive impoundments (Kadlec 1962). Stabilizing water levels, particularly at high levels, can be detrimental; and periodic drying and flooding is beneficial for establishment of desired aquatic vegetation (Weller 1978, 1981:70). The need for seasonal instability should not be equated with erratic water level changes at any time of the year (Weller 1981:70). Wildlife productivity will likely increase as wetlands experience a regular flooding cycle (Mitsch and Gosselink 1986:430).

2. Backwater Lakes With Water Level Management

a. General Overview. Prior to construction of the navigation system, water levels typically dropped during the summer months allowing backwater lakes to consolidate. This drying effect encouraged emergent aquatic plants, such as bulrush and arrowhead to grow. With the more stable water levels created by the navigation pools, this low-water effect and drying of sediments no longer occurs. Plant beds that depend on this drying process have decreased in extent or disappeared entirely. Stands of perennial emergent aquatic plants are important to fish and wildlife populations because they provide food, shelter, and dissolved oxygen. Hence, a backwater lake with water level management may be implemented to help improve conditions for the growth of aquatic vegetation.

Similar to MSMUs, backwater lakes with water level management are typically designed to include water containment, water supply, and water control structures. These are similar to those described for MSMUs. Backwater lakes with water level management are listed below. The design features for a backwater lake with water level management are described in Section D.

Batchtown HREP, Pool 25, UMR RM 242.5-246.0, Calhoun Co., IL, MVS
Banner Marsh HREP, LaGrange Pool, IWW RM 138.0-144.0, Fulton Co. and Peoria Co., IL, MVR
Bay Island HREP, Pool 22, UMR RM 311.0-312.0, Marion Co., MO, MVR
Bussey Lake HREP, Pool 10, UMR, Clayton Co., IA, MVP
Calhoun Point HREP, Pool 26, UMR RM 221.0-221.0, Calhoun Co., IL, MVS
Clarksville Refuge HREP, Pool 24, UMR RM 275.0-275.0, Pike Co., MO, MVS
Finger Lakes HREP, Pool 5, UMR, Wabasha Co., MN, MVP
Fox Island HREP, Pool 20, UMR RM 353.5-358.5, Clark Co., MO, MVR
Lake Chautauqua HREP, LaGrange Pool, IWW RM 124.0-129.5, Mason Co., IL, MVR
Lake Odessa HREP, Pools 17-18, UMR RM 435.0-440.0, Louisa Co., IA, MVR
Long Meadow Lake HREP, Minnesota River, Hennepin Co., MN, MVP
Peoria Lake HREP, Peoria Pool, IWW RM 162.0-181.0, Peoria Co. and Woodford Co., IL, MVR
Princeton Refuge HREP, Pool 14, UMR RM 504.0-506.4, Scott Co., IA, MVR
Rice Lake HREP, LaGrange Pool, IWW RM 132.0-138.0, Fulton Co., IL, MVR
Rice Lake HREP, Minnesota River RM 15.0-17.5, Scott Co. and Hennepin Co., MN, MVP
Small Scale Drawdown HREP, Pool 5, UMR RM 746.0-746.0, Buffalo Co., WI, MVP
Stump Lake HREP, Alton Pool, IWW RM 7.2-12.7, Jersey Co., IL, MVS
Swan Lake HREP, Alton Pool, IWW RM 5.0-13.0, Calhoun Co., IL, MVS
Trempealeau NWR HREP, Pool 6, UMR RM 718.0-724.0, Trempealeau Co., WI, MVP

MVR – Rock Island District; MVS – St. Louis District; MVP – St. Paul District

b. Biota and Habitat Considerations. Generally, the goal of a backwater lake with water level management is aquatic habitat restoration with the objective of providing suitable habitat for waterfowl and fisheries. Water level management of a backwater lake consists of a temporary seasonal increase or decrease in water elevations to mimic natural hydrologic regimes in order to improve large areas of shallow aquatic habitat.

D. DESIGN FEATURES COMMON FOR WATER LEVEL MANAGEMENT

Water level management projects, to include MSMUs and backwater lakes, have several similar design features important to the proper operation and maintenance of these systems. These features are described in the following sections.

1. Exterior Berms, Interior Berms, and Overflow Spillways

a Design Considerations. Two general design criteria for this project feature are to construct a reliable embankment system that provides adequate flood protection to meet the sponsor's seasonal and/or annual management goals and locate borrow sites in areas that improve the suitable habitat for migratory birds.

b. Embankment Height. When designing the height of the embankment system, it is important to minimize interior sedimentation and to provide protection against frequent flooding for reliable water level management but on the other hand, it can also be important to maintain connectivity with the river. In addition, the desired operating levels of the system also need to be considered. Therefore, the embankment height needs to be carefully evaluated. One approach for determining the embankment height is to consider various flood elevations (2- year, 5-year, 10-year, 15-year, 20-year, 25-year, etc.) and determine how many times each flood elevation has been exceeded based on the data available. Then evaluate the additional cost of raising the embankment system to a higher flood elevation versus the decrease in the exceedance rate. The approximate embankment heights for some HREPs are listed in the table 5-2.

Table 5-2. HREP Embankment Height

Project	Feature	Embankment Height (Flood Level)
Andalusia	Levee	2 year
Banner Marsh	Levee	50 year
Bay Island	Levee	2 year
Clarksville	Levee	20 year
Lake Odessa	Levee	varies
	Upper Spillway	17 year
	Lower Spillway	10 year
Princeton	Levee	15 year
Rice Lake	Spillway	2 year
Spring Lake	Levee	50 year
	Cross Dike (Interior Berm)	5 year
Stump Lake	Levee	3 to 4 year

c. Embankment Slopes. If the exterior berm is located adjacent to a major river, its profile parallel to that river may be sloped upstream to allow for gradual overtopping during flood events, which could minimize damage potential. Top widths for exterior and interior berms are typically a minimum of 10 feet, especially for those embankment systems that are also used for access. (At times the top of the berms are used as a roadway for embankment inspections or maintenance.) Side slopes are typically a minimum of 3H:1V. Flatter side slopes can be desired to minimize rodent damage and to minimize erosion caused by overtopping. If site conditions vary, consider multiple design cross section templates as a single design cross section template doesn't always fit the actual field conditions encountered during construction. Design cross section templates should be applicable to all field conditions.

d. Cells. A MSMU may have a single exterior berm (1-celled) or consist of multiple cells through the construction of interior berms. When determining whether the embankment system should be single or multiple celled, consider the existing site topography. If the site is relatively flat, a single cell may be adequate. If the site varies in elevation, multiple cells may be desired to maximize the acreage of ideal water depth. In addition, large MSMUs may be portioned into multiple cells for management purposes. On the other hand, it can also be desired to minimize the number of cells to increase connectivity and create larger contiguous areas required by some species. The top elevation of an interior berm is typically set to provide a minimum freeboard of 2 feet during the highest ponding scenario.

e. Spillways. To provide controlled overtopping of an embankment system, overflow spillways are constructed, typically at the downstream end of the site, at an elevation lower than the exterior berm. This elevation provides for overtopping during a lesser flood event. During a flood event, the overflow spillway allows rapid filling of the MSMU interior prior to overtopping of the exterior berm. The spillway provides a defined location for filling the cells that can be adequately armored and protected against erosion. An overtopping analysis should be conducted to determine the elevation difference between the exterior berm and the overflow spillway.

f. Embankment Material. When considering options for borrow material for the embankment system, it may be beneficial to use on-site material that is suitable. The utilization of interior borrow areas offers additional habitat benefit by converting existing cropland to non-forested wetland. Ideally, these areas would be developed as large and shallow, which would not only maximize habitat benefits but may also yield the most suitable impervious borrow material. Essentially, these borrow areas may be considered potholes. Dredged material from within or outside the embankments may also be used to construct the berms. Using dredged material may provide additional aquatic habitat for the HREP.

g. Embankment Protection. HREPs that include moist soil units typically hold water for extended periods of time. To the greatest extent possible provide bank stabilization methods above and below the design operating water levels. Typically, vegetative bank stabilization is often planted on embankments to help prevent scouring. Stone protection may also be required in some instances. For embankments that will be exposed to frequent recreational traffic, consider establishing slow-no-wake zones to help minimize erosion, especially if the embankment is constructed of clay material and is not protected with riprap.

h. Maintenance. Maintenance of the exterior berms, interior berms, and overflow spillways should include project inspections on an annual basis (ideally after the area is drained) in addition to immediately following a high water event. Project inspections should determine if the following conditions exist:

- settlement, slough, or loss of section
- wave wash and scouring
- overtopping erosion
- inadequate vegetative cover (too much or not enough)
- unauthorized grazing or traffic

- encroachments
- unfavorable tree/shrub growth
- seepage distress

Corrective action should be taken upon discovery of any adverse conditions.

i. Case Studies. Constructed HREPs with an embankment feature are listed here.

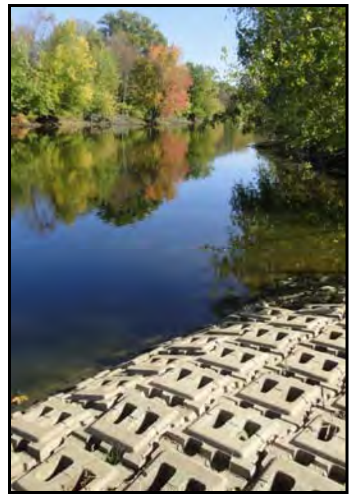
Andalusia Refuge HREP, Pool 16, UMR RM 462.0-463.0, Rock Island Co., IL, MVR
Banner Marsh HREP, LaGrange Pool, IWW RM 138.0-144.0, Fulton Co. and Peoria Co., IL, MVR
Bay Island HREP, Pool 22, UMR RM 311.0-312.0, Marion Co., MO, MVR
Clarksville Refuge HREP, Pool 24, UMR RM 275.0-275.0, Pike Co., MO, MVS
Guttenberg Waterfowl Ponds HREP, Pool 11, UMR RM 614.0-615.0, Grant Co., WI, MVP
Lake Chautauqua HREP, LaGrange Pool, IWW RM 124.0-129.5, Mason Co., IL, MVR
Lake Odessa HREP, Pools 17-18, UMR RM 435.0-440.0, Louisa Co., IA, MVR
Pharrs Island HREP, Pool 24, UMR, Pike Co., MO, MVS
Pool Slough HREP, Pool 9, UMR RM 673.0-673.0, Allamakee Co., IA MVP
Princeton Refuge HREP, Pool 14, UMR RM 504.0-506.4, Scott Co., IA, MVR
Rice Lake HREP, LaGrange Pool, IWW RM 132.0-138.0, Fulton Co., IL, MVR
Rice Lake HREP, Minnesota River RM 15.0-17.5, Scott Co. and Hennepin Co., MN, MVP
Spring Lake HREP, Pool 13, UMR RM 532.5-536.0, Carroll Co., IL, MVR
Stump Lake HREP, Alton Pool, IWW RM 7.2-12.7, Jersey Co., IL, MVS
Swan Lake HREP, Alton Pool, IWW RM 5.0-13.0, Calhoun Co., IL, MVS
Trempealeau NWR HREP, Pool 6, UMR RM 718.0-724.0, Trempealeau Co., WI, MVP

MVR – Rock Island District; MVS – St. Louis District; MVP – St. Paul District

j. Photographs. Constructed HREPs with berms and/or spillways are shown here.

Photographs 5-1a and b. Andalusia Refuge HREP, Pool 16, UMR RM 462.0-463.0, Rock Island Co., IL, MVR

Photograph 5-2. Princeton Refuge HREP, Pool 14, UMR RM 504.0-506.4, Scott Co., IA, MVR



Photographs 5-3a and b. Lake Odessa HREP, Pools 17-18, UMR RM 435.0-440.0, Louisa Co., IA, MVR

k. References

EM 1110-2-1603, *Engineering and Design - Hydraulic Design of Spillways,* CECW-ED-H, 16 Jan 1990 (original) 31 Aug 1992 (errata #1)

EM 1110-2-1913, *Engineering and Design - Design and Construction of Levees*, CECW-EG, 30 Apr 2000

EP 415-1-261 (Volume 2), Construction - Quality Assurance Representative's Guide - Pile Driving, Dams, Levees and Related Items, CEMP-CE, 31 Mar 1992

2. Pump Stations and Wells

a. Design Considerations. Water can be introduced or removed from a MSMU or backwater lake through the use of a pump station, portable pumps, wells or a water control structure. Pumps can obtain either surface water, typically from a river, or groundwater.

b. Surface Water. When evaluating a pump station versus a well (i.e. surface water versus ground water), keep in mind that reuse of surface water is desired where practicable. Surface water is often used as a source due to its abundance and ease of access. When surface water is used, it can remove sediment from its source, and add potentially nutrient rich sediment to the MSMU or backwater lake. Additionally, the use of surface water can remove nitrogen and phosphorous from the river system, with the nutrients eventually being uptaken by plant organisms within the MSMU.

Inlet and/or outlet channels from the source of surface water to the pump stations if needed have routinely had sedimentation challenges. To the greatest extent possible, locate pump stations adjacent to the river or as close to the river as possible to minimize channel lengths.

c. Groundwater. The volume of water required will generally dictate whether a groundwater well can be feasibly constructed. Groundwater wells are limited in capacity due to available well yield from the aquifer, construction limitations, commercially available well pump size, and availability of utility power. There is also a potential of encountering poor groundwater quality such as high sulfur, etc. It may be necessary to incorporate provisions into the design to deal with situations where testing of groundwater quality reveals problems.

d. Pump Housing. Pump stations can be designed to have the intake sump and pumps with associated equipment all in one structure or they can be separate. The equipment for both pump stations and wells is required to be at or above certain flood elevations and will depend on where the project is located. Pumping stations can either be a permanent station or be mobile, including floating type pumping plants.

e. Water Direction. Pump stations can be designed to pump from the river to the MSMU, from the MSMU to the river, or be multi-directional to pump to multiple MSMU's as well as either way. Extra flexibility may be desired by the project sponsor, although water control could be obtained through the use of various closure structures if so designed.

f. Pump Size. When determining the size of the pumps for a pump station or well, a minimum of three variables need to be considered; the evaporation rate, the seepage rate, and the desired fill rate.

g. Access Hatches. Design hatches and grating to have locking mechanisms when open so that the hatches to do not close unexpectedly causing a safety hazard.

h. Power Source. Pumps may be electric or diesel driven depending upon the availability of utility power and user needs. Electric driven pump stations have the advantage of being quieter to operate (little vibration), easier automation, and less routine maintenance. They may also be submerged and require less labor time to operate. Some of the disadvantages are that the electrical equipment must be protected from flooding, available utility power can limit capacity, high demand charge, and usually larger more elaborate structures are required to house electrical equipment. Since electrical equipment is subject to damage from high water, ensure that it is placed above the 500 year (or higher if possible) flood elevation.

Diesel driven pump stations have the advantage of being ideally suited where utility power in unavailable, they have a large capacity, can be permanently mounted pumps with submersible gear drives, can be mounted vertically or angle mounted, can be made trailer mounted to reduce the threat of flooding, and the drive arrangements afford flexibility (direct, belt, hydraulic). Disadvantages to diesel driven pumps are they are noisy to operate, require more routine maintenance, capacity and availability of on-site fuel supply can be restrictive, and are difficult to automate.

i. Equipment Testing. Ensure the contract specifications include testing for all pump station equipment to include pumps, floats, surge protectors, humidity devices, etc. All pump station equipment should be checked, inspected, and verified after installation by the Contractor before finally acceptance.

j. Maintenance. Maintenance of a pump station or well should include project inspections on an annual basis (ideally after the area is drained) in addition to immediately following a high water event. Pump station inspections should be documented using the pump station rating guidelines for continuing eligibility inspections to include the following items as a minimum where applicable:

- structural steel
- structural concrete
- displaced/missing riprap
- electrical lighting/standby generator
- discharge pipe
- sump
- hydraulic pump
- stoplogs

Corrective action should be taken upon discovery of any deficiencies found during the inspection.

k. Case Studies. Constructed HREPs with pump stations and wells are as follows:

Andalusia Refuge HREP, Pool 16, UMR RM 462.0-463.0, Rock Island Co., IL, MVR
Banner Marsh HREP, LaGrange Pool, IWW RM 138.0-144.0, Fulton Co. and Peoria Co., IL, MVR
Batchtown HREP, Pool 25, UMR RM 242.5-246.0, Calhoun Co., IL, MVS
Bay Island HREP, Pool 22, UMR RM 311.0-312.0, Marion Co., MO, MVR
Calhoun Point HREP, Pool 26, at the confluence of IWW and UMR RM 220.0, Calhoun Co., IL, MVS
Clarksville Refuge HREP, Pool 24, UMR RM 275.0-275.0, Pike Co., MO, MVS
Cuivre Island HREP, Pool 26, UMR RM 233.0-239.0, Lincoln Co. and St. Charles Co., MO, MVS
Lake Chautauqua HREP, LaGrange Pool, IWW RM 124.0-129.5, Mason Co., IL, MVR
Lake Odessa HREP, Pools 17-18, UMR RM 435.0-440.0, Louisa Co., IA, MVR
Peoria Lake HREP, Peoria Pool, IWW RM 162.0-181.0, Peoria Co. and Woodford Co., IL, MVR
Princeton Refuge HREP, Pool 14, UMR RM 504.0-506.4, Scott Co., IA, MVR
Rice Lake HREP, LaGrange Pool, IWW RM 132.0-138.0, Fulton Co., IL, MVR
Spring Lake HREP, Pool 13, UMR RM 532.5-536.0, Carroll Co., IL, MVR

Stump Lake HREP, Pool 26, IWW RM 7.0-13.0, Jersey Co., IL, MVS
Swan Lake HREP, Alton Pool, IWW RM 5.0-13.0, Calhoun Co., IL, MVS
Trempealeau NWR HREP, Pool 6, UMR RM 718.0-724.0, Trempealeau Co., WI, MVP

MVR – Rock Island District; MVS – St. Louis District; MVP – St. Paul District

l. Photographs. Constructed HREPs with pump stations are shown here.

Photographs 5-4a and b. Andalusia Refuge HREP, Pool 16, UMR RM 462.0-463.0, Rock Island Co., IL, MVR

Photograph 5-5. Portable Pump-Lake Odessa HREP, Pools 17-18, UMR RM 435.0-440.0, Louisa Co., IA, MVR

m. References

EM 1110-2-3104, Engineering and Design - Structural and Architectural Design of Pumping Stations, CECW-ED, 30 Jun 1989

ER 1110-2-100, Engineering and Design - Periodic Inspection and Continuing Evaluation of Completed Civil Works Structures, CECW-EP, 15 Feb 1995

3. Stoplog Structures

a. Design Considerations. A general design criterion for this project feature is to construct a structure with operational flexibility that provides the site manager with the capability to meet seasonal and/or annual management goals. Stoplogs can be placed in various types of structures to meet the sizing requirements for raising or lowering water levels. Additionally, the design of the stoplogs themselves can vary widely. Using stoplog structures can be an advantage because they are relatively inexpensive and require low maintenance. Some disadvantages include the following:

- Removing a stoplog can, in some cases, require more than one-person to operate.
- When the head over the stoplogs is high, removal can become nearly impossible.
- Stoplogs with eyes at top are difficult to remove and are often hard to hook, which can also cause problems with sealing properly.

b. Structure Material. Stoplog structures may be constructed of various materials, such as concrete, corrugated metal pipe (CMP), combination concrete and CMP, PVC, or steel.

c. Concrete stoplog structures may have single or multiple bays. The concrete structure may be cast-in-place or precast. Additionally, the structure may or may not have footings. Dewatered versus in the wet construction methods should be considered, especially if control of construction costs are critical.

d. CMP stoplog structures generally consist of a 5-foot diameter riser pipe.

e. PVC stoplog structures have not been used extensively for HREP projects but have proven to be successful on other Corps projects so they should be considered for future HREP projects (http://www.agridrain.com/watercontrolproductsinline.asp). Stoplog structures may also be designed to have a combination of both stoplogs and sluice gates. The ability to resist deflection and warping must be considered. Protection against damage from ultraviolet radiation is important because the breakdown of the outer surface can expose glass fibers.

f. Sheet pile cells may be incorporated into stoplog structures as abutments (Batchtown, Swan Lake and Calhoun Point) or stoplog structures may incorporate internally tied-back Z-shaped sheet pile wing and face walls (Calhoun Point). Concrete footing structures at the top of each abutment support access bridges and stoplog support framing. These footings may be soil-founded (Batchtown) or pile-founded within the retained embankment (Calhoun Point) as local conditions require.

g. Structure Location. Inlet and/or outlet channels from the main channel to the stoplog structures if needed have routinely had sedimentation challenges. To the greatest extent possible, locate stoplog structures adjacent to the river or as close to the river as possible to minimize side channel lengths. Soil borings are recommended at the proposed location of structures to include groundwater elevations. The soils should be evaluated to determine if they are suitable for the structure foundation and if not, what kind of working platform is needed. Ground water elevations can help identify the need for a cofferdam and/or dewatering system during construction.

h. Structure Height. Structures can vary in height to meet customer requirements. At Swan Lake, a number of both one-foot-high and six-foot-high stoplogs are being provided for flexibility in operation. At Calhoun Point, one-foot-high stoplogs that can be ganged together in the field are being provided. In general, the structure should be located and designed to allow for appropriate drainage or flooding of the site, and to ensure that there is adequate height to maintain water levels upstream of the structure.

i. Structure Top Width. For larger structures, if vehicular access across a structure is required, the weight and width of the equipment must be considered.

j. Structure Safety. If operator access is required, appropriate safety measures for guardrails, steps, etc. must be included. Additionally, operator safety should be considered in developing structure features. Non-skid grating and guardrails should be provided on catwalks, etc. Safety features for access to the smaller structures must be considered such as locking devices for hinged hatches.

k. Structure Protection. Ensure that sufficient riprap/bank stabilization is placed around inlet/outlet of gated structures, even if erosion is not a concern. This will prevent wildlife from burrowing next to the structure, which has been a maintenance issue at a few constructed projects. The tendency is to keep the stabilization to a minimum when going for the maximum is usually the better approach.

l. Stoplog Material

Aluminum stoplogs generally weigh less but cost more. While the material weight for aluminum stoplogs is less than wood, hollow stoplogs can accumulate internal silt and thus additional lifting weight over time. Aluminum stoplogs have been designed to have rubber stripping along the bottom and sides to provide a tighter seal. Options for aluminum stoplogs include extruded cross-sections (for individual 1-foot stoplogs) or fabricated cross sections of skin plates and connecting members (for 1-foot or higher stoplogs). Aluminum stoplogs are also subject to being stolen when aluminum recycling costs are high.

Wood stoplogs are buoyant and require ballasting or some type of mechanism to prevent from floating. Wood stoplogs may have a tendency to seal better as wood will swell when saturated. To help with sealing, wood stoplogs have been designed to have grooves so that they “interlock;” when installed, however, this is not always the case, such as at Swan Lake.

m. Stoplog Bay Widths. A stoplog structure can involve a series of bays. The stoplog bay width depends on local user requirements. In Rock Island District, a five foot bay is often used. At Batchtown (in St. Louis District), several structures are across channels where duck blind access is required. A clear width in each bay of ten feet between stoplog supports, and head clearance of five feet between the maximum water level and the low surface of the access bridge, is provided. At Swan Lake, where such access is not required, the clear opening in each bay is only four feet. If a number of similar structures are anticipated at a project site, using similar bay widths, and therefore similar stoplogs throughout, can provide interoperability.

n. Stoplog Storage. Stoplogs may be stored either off site or on-site, such as in a pump house. If stored on-site, keep stoplogs at the highest elevation possible. It is important to establish storage capabilities of the site managers during the design process.

o. Stoplog Protection. Stoplog structures need to be protected from vandalism, theft, and unauthorized use. This can be accomplished through use of padlocks and locking bars. The safety of stoplog structures can be provided through use of inlet/outlet guards, ladders, guardrails, and other such devices.

p. Stoplog Lifting Devices. A stoplog lifting hook is typically furnished for the installation and removal of the stoplogs. Lifting devices should be designed for easy transportation and use, especially during high flows. Stop log hoists may be used to manipulate the structure. Lifting devices can be manual or power-assisted. Electric or hydraulic hoists can be used for raising and lowering stoplogs. The lifting equipment can be supported on a trolley beam running across all bays or on a jib crane. The support requirements for a trolley beam or job crane will determine to some extent the layout of the supporting structures at the sides of the channel to be controlled. Jib crane manufacturers can provide anchor bolt patterns and minimum footing requirements to be used in support structure layout. The design of the lifting device should take into consideration the equipment and/or machinery that the owner has on hand or is readily available to them. Keep in mind when designing a stoplog structure that some site managers may prefer a one-person operation when installing and removing stoplogs. This can become difficult when the head is too high over the stoplogs, the stoplogs are too heavy, and/or the lifting devices are too bulky.

q. Operation. Stoplog structures should be operated so that when the MSMU is in use or the river water levels are expected to rise, the stoplogs should be installed and are to remain in place until one of the following occurs:

- flood waters recedes,
- project no longer in use, or
- overtopping of the exterior berm is anticipated

r. Maintenance. Maintenance of stoplog structures should include project inspections on an annual basis (ideally after the area is drained) in addition to immediately following a high water event. Project inspections should ensure the following:

- stoplogs, slots, keepers, staff gages, and lifting hooks are in good condition
- steel rails, posts, grating, and fasteners are in good condition
- concrete is in good condition
- inlet and outlet channels are open
- trash, debris, and sediment are not accumulating in and around the structure
- erosion, seepage, and encroachments are not occurring adjacent to the structure which might endanger its function
- riprap is not displaced or missing

Corrective action should be taken upon discovery of any adverse conditions at the structures.

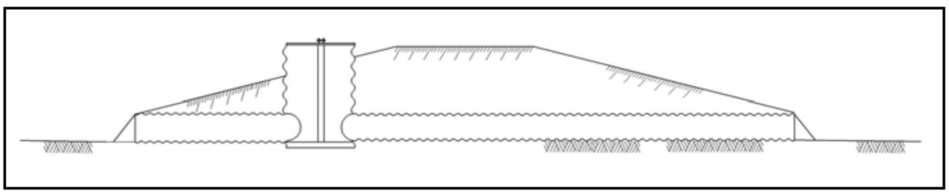
s. Case Studies. Constructed HREPs with stoplog include the following:

Ambrough Slough HREP, Pool 10, UMR, Crawford Co., WI, MVP
Banner Marsh HREP, LaGrange Pool, IWW RM 138.0-144.0, Fulton Co. and Peoria Co., IL, MVR
Batchtown HREP, Pool 25, UMR RM 242.5-246.0, Calhoun Co., IL, MVS
Bay Island HREP, Pool 22, UMR RM 311.0-312.0, Marion Co., MO, MVR
Calhoun Point HREP, Pool 26, UMR RM 221.0-221.0, Calhoun Co., IL, MVS
Cuivre Island HREP, Pool 26, UMR RM 233.0-239.0, Lincoln Co. and St. Charles Co., MO, MVS
Fox Island HREP, Pool 20, UMR RM 353.5-358.5, Clark Co., MO, MVR
Guttenberg Waterfowl Ponds HREP, Pool 11, UMR RM 614.0-615.0, Grant Co., WI, MVP
Lake Chautauqua HREP, LaGrange Pool, IWW RM 124.0-129.5, Mason Co., IL, MVR
Lake Odessa HREP, Pools 17-18, UMR RM 435.0-440.0, Louisa Co., IA, MVR
Long Meadow Lake HREP, Minnesota River, Hennepin Co., MN, MVP
Peoria Lake HREP, Peoria Pool, IWW RM 162.0-181.0, Peoria Co. and Woodford Co., IL, MVR
Pleasant Creek HREP, Pool 13, UMR RM 548.7-552.8, Jackson Co., IA, MVR
Pool Slough HREP, Pool 9, UMR RM 673.0-673.0, Allamakee Co., IA MVP
Potters Marsh HREP, Pool 13, UMR RM 522.5-526.0, Carroll Co. and Whiteside Co., IL, MVR
Princeton Refuge HREP, Pool 14, UMR RM 504.0-506.4, Scott Co., IA, MVR
Rice Lake HREP, LaGrange Pool, IWW RM 132.0-138.0, Fulton Co., IL, MVR
Rice Lake HREP, Minnesota River RM 15.0-17.5, Scott Co. and Hennepin Co., MN, MVP
Spring Lake HREP, Pool 13, UMR RM 532.5-536.0, Carroll Co., IL, MVR
Stump Lake HREP, Alton Pool, IWW RM 7.2-12.7, Jersey Co., IL, MVS
Swan Lake HREP, Pool 26, IWW RM 5.0-13.0, Calhoun Co., IL, MVS

MVR – Rock Island District; MVS – St. Louis District; MVP – St. Paul District

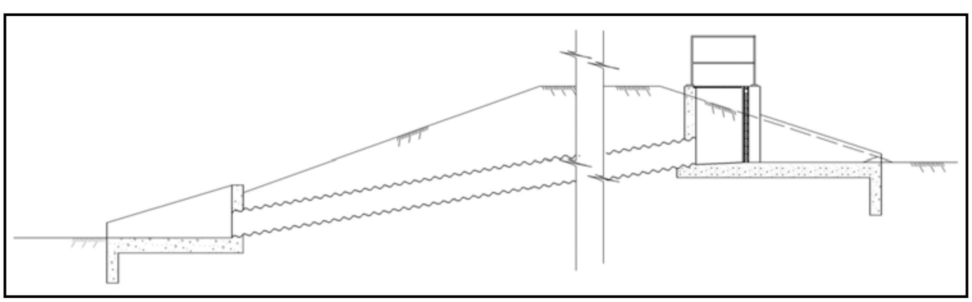
t. Photographs and Figures. Constructed HREPs with stoplog structures are shown in the following photographs:





Photographs 5-6a, b, and c. Banner Marsh HREP, LaGrange Pool, IWW RM 138.0-144.0, Fulton and Peoria Counties, IL, MVR





Photographs 5-7a, b, and c. Potters Marsh HREP, Pool 13, UMR RM 522.5-526.0, Carroll and Whiteside Counties, IL, MVR

Photographs 5-8a and b. Bay Island HREP, Pool 22, UMR RM 311.0-312.0, Marion Co., MO, MVR

Photographs 5-9a and b. Princeton Refuge HREP, Pool 14, UMR RM 504.0-506.4, Scott Co., IA, MVR

Photographs 5-10a and b. Spring Lake HREP, Pool 13, UMR RM 532.5-536.0, Carroll Co., IL, MVR

u. References

EM 1110-2-2705, Engineering and Design - Structural Design of Closure Structures for Local Flood Protection Projects, CECW-ED, 31 Mar 1994

Agri Drain Corporation, Inline Water Level Control Structures, http://wwwagridraincom/watercontrolproductsinlineasp

Agri Drain Corporation, Inlet Water Level Control Structures, http://wwwagridraincom/watercontrolproductsinletasp

EM 385-1-1, Safety – Safety and Health Requirements, CESO-ZA, 03 Nov 2003

EM 1110-2-2100, Stability Analysis of Concrete Structures, CECW-CE, 01 Dec 2005

EM 1110-2-2102, Engineering and Design – Waterstops and Other Preformed Joint Materials for Civil Works Structures, CECW-EG, 30 Sep 2005

EM 1110-2-2104, Engineering and Design – Strength Design for Reinforced Concrete Hydraulic Structures, CECW-ED, 30 Jun 1992 (original), 20 Aug 2003 (Change 1)

EM 1110-2-2105, Engineering and Design – Design of Hydraulic Steel Structures, CECW-ED, 31 Mar 1993 (Original), 31 May 1994 (Change 1)

EM 1110-2-2503, Engineering and Design – Design of Sheet Pile Cellular Structures, Cofferdams and Retaining Structures, CECW-EP, 20 Sep 1989 (Original), 11 Jun 1990 (Errata sheet)

EM 1110-2-2504, Engineering and Design – Design of Sheet Pile Walls, CECW-ED, 31 Mar 1994

EM 1110-2-2906, Engineering and Design – Design of Pile Foundations, CECW-ED, 15 Jan 1991

4. Gated Structures

a. Design Considerations. The primary purpose of a gated structure is to provide gravity drainage from the MSMU. It may be desirable to have at least one gated structure installed within each cell. A gated structure may also be used to enhance MSMU filling operations. If high water events were to occur during the late summer and fall, the gated structure could be opened to help capture water, thereby decreasing the pumping requirements. In addition, the gated structure may serve as an additional opening for water to enter the MSMU prior to overtopping events.

A secondary goal of a gated structure may be to increase dissolved oxygen (DO) levels. Gated structures can be used to help control and maintain water quality in backwaters. If increased DO levels are desired, the size of the gated structure should consider the amount of water needed to provide adequate dissolved oxygen during critical times of the year.

Concrete gated structures may be cast-in-place or precast with the piping being precast reinforced concrete pipe. In some cases, this might be specified as the Contractor's option. Weight and size limitations might restrict this choice. Gated structures may be constructed of CMP. The inverts may be reinforced with riprap. Desired level of durability and dewatering requirements during construction will influence the choice of structure. It is important to consider the expected life of a CMP structure when designing this type of feature. In addition to material type, another factor to consider in the design of a gated structure is whether or not fish passage is desired.
The type of gate that may be installed depends on the type of structure. Sluice gates requiring a flat back for installation require a concrete structure. Other types of gates (for example, gates which can be installed on the end of a pipe) are not as dependent upon the type of structure. The structure must provide an operating platform from which the gate may be manipulated and which supports any equipment required to do so. This platform can be steel or fiberglass grating. Guardrails should be provided where required by the safety manual. In addition, even if erosion is not a concern, sufficient riprap/bank stabilization will need to be placed around the inlet/outlet of a gated structure. This will prevent wildlife from burrowing next to the structure, which has been an issue at a few constructed projects. The tendency is to keep the stabilization to a minimum when actually, the maximum is usually the better approach.

Inlet and/or outlet channels from the main channel to the gated structures have routinely raised sedimentation challenges. To the greatest extent possible, locate gated structures adjacent to the river, or as close as possible, to minimize side channel lengths. Soil borings are recommended at locations of structures with groundwater elevations. The soils should be evaluated to determine if they are suitable for the structure foundation and if not, determine what kind of working platform is needed. Ground water elevations can help identify the need for a cofferdam and/or dewatering system. Controlling and maintaining debris is a primary consideration in designing the inlet to these structures. Trash racks, flap gates, wooden piles, sheep and cattle fencing, and a number of other techniques have been used to prevent debris from plugging these structures. Debris can be large (trees and logs) or small (floating vegetation). In some situations small debris can be flushed from the conduit entrance or outlet by increasing discharge levels and velocities in the system.

b. Case Studies. Constructed HREPs with gated structures are listed below.

Andalusia Refuge HREP, Pool 16, UMR RM 462.0-463.0, Rock Island Co., IL, MVR
Batchtown HREP, Pool 25, UMR RM 242.5-246.0, Calhoun Co., IL, MVS
Brown's Lake HREP, Pool 13, UMR RM 545.8, Jackson Co., IA, MVR
Bussey Lake HREP, Pool 10, UMR, Clayton Co., IA, MVP
Calhoun Point HREP, Pool 26, UMR RM 221.0-221.0, Calhoun Co., IL, MVS
Clarksville Refuge HREP, Pool 24, UMR RM 275.0-275.0, Pike Co., MO, MVS
Cuivre Island HREP Pool 26, UMR RM 233.0-239.0, Lincoln Co. and St. Charles Co., MO., MVS
Dresser Island HREP, Pool 26, UMR RM 206.0-209.0, St. Charles Co., MO, MVS
Finger Lakes HREP, Pool 5, UMR, Wabasha Co., MN, MVP
Guttenberg Waterfowl Ponds HREP, Pool 11, UMR RM 614.0-615.0, Grant Co., WI, MVP
Island 42 HREP, Pool 5, UMR, Wabasha Co., MN, MVP
Lake Chautauqua HREP, LaGrange Pool, IWW RM 124.0-129.5, Mason Co., IL, MVR
Lake Odessa HREP, Pools 17-18, UMR RM 435.0-440.0, Louisa Co., IA, MVR
Long Lake HREP, Pool 7, UMR, Trempealeau Co. and La Crosse Co., WI, MVP
Long Meadow Lake HREP, Minnesota River, Hennepin Co., MN, MVP
Pharrs Island HREP, Pool 24, UMR, Pike Co., MO, MVS
Princeton Refuge HREP, Pool 14, UMR RM 504.0-506.4, Scott Co., IA, MVR
Spring Lake HREP, Pool 13, UMR RM 532.5-536.0, Carroll Co., IL, MVR
Stump Lake HREP, Alton Pool, IWW RM 7.2-12.7, Jersey Co., IL, MVS
Swan Lake HREP, Alton Pool, IWW RM 5.0-13.0, Calhoun Co., IL, MVS
Trempealeau NWR HREP, Pool 6, UMR RM 718.0-724.0, Trempealeau Co., WI, MVP

c. Photographs. Constructed HREPs with gated structures are shown below.

Photograph 5-11. Andalusia Refuge HREP, Pool 16, UMR RM 462.0-463.0, Rock Island Co., IL, MVR

Photograph 5-12. Princeton Refuge HREP, Pool 14, UMR RM 504.0-506.4, Scott Co., IA, MVR

Photograph 5-13. Guttenberg Waterfowl Ponds HREP, Pool 11, UMR RM 614.0-615.0, Grant Co., WI, MVP

d. Reference

EM 1110-2-3104, Engineering and Design - Structural and Architectural Design of Pumping Stations, Appendix C, CECW-ED, 30 Jun 1989

5. Sheet Pile Cells

a. Design Considerations. Sheet pile cells are fabricated from flat PS-series steel sheets. The number of sheets required for a particular radius cell is standard for a particular width sheet and can be ascertained from manufacturers' handbooks. A cutoff wall of Z-shaped steel sheet piles is driven between the two cells and capped with a sill beam (cast-in-place or precast and grouted onto the cells). Fabricated piles are used to create the connection between the cells and the cutoff wall.

Because the Government is required to purchase American steel, the sources for sheet piling and cross-section profiles allowed are limited. This requirement must be considered in the design stage of a project so the correct cross-sections can be included in the Plans and Specifications. PS- and Z-profile sheets are rolled in this country by Chaparral Steel (http://www.chapusa.com/), which distributes through L.B. Foster (http://www.lbfoster.com/). Additional information on these products is available at http://www.sheet-piling.com/main. Another American supplier of these products is Nucor-Yamato steel (http://www.nucoryamato.com/).

Where sheet pile cells are used as abutments for water control structures, the cells are assumed to be stable within a plane parallel to the axis of the berm (i.e., if the end of the berm is stable in itself, a cell situated within the end of the berm will be stable). Stability in a plane transverse to the axis of the berm is checked, based on the depth of the sheet piling and the internal pressures and external pressures on the cell. The internal pressures will be influenced by the method with which the cell fill is placed.

The need for dewatering of the site prior to placement of the cells must also be considered, because it affects means of construction as well as cost.

Developing a clearly-defined construction sequence is critical for proper installation of the cells. Placement of the cells relative to each other in the field should consider the "bulge" the cells may experience after fill is placed. The resulting clear distance between cells must be considered with regard to installation of footings on top of the cells and stoplog support appurtenances.

Special connection details (e.g., bent plates above the sill analogous to the cutoff wall fabricated piles below the sill) are necessary to provide watertight closure between the cells and the stoplog supports. Selecting steel details that will accommodate the final disposition of the cells, and allowing extra distance between the driven cells to account for bulge, can assist in successful erection of appurtenant details.

Sheet pile cells have provided an opportunity for recycling steel sheet piling originally used for temporary purposes (e.g., sheet piling that had been used in the Melvin Price Locks and Dam cofferdam has since been utilized in cell abutments at EMP projects). If recycled sheet piling is being considered, the condition of the piling needs to be evaluated to include a inspection of the interlocks and tips as well as damage to the sheeting itself.

Concrete footings installed on top of the cells support structural/mechanical features such as access bridges, jib cranes, etc. The sheet piling can be used as part of the formwork for these footings. The footings may be supported on the cell fill alone or on foundation piles driven through the fill, as conditions warrant.

Placement of a concrete slab on top of the cell will prevent loss of cell fill in the event a cell is overtopped. Provision of plugged holes in the slab will allow grouting beneath the slab if excessive fill settlement should occur.

Guardrail should be installed around the tops of cells in accordance with the safety manual. In lieu of installing a toeboard, the sheet piling may be cut off four inches above the top of the cell fill/slab. Fiberglass-reinforced plastic guardrails have been used at some locations (Swan Lake); however, because of ultraviolet deterioration and difficulty in making repairs should these items be damaged during floods, wire rope guardrails are an appropriate alternative (Batchtown, replacement of guardrails at Swan Lake).

b. Case Studies. Constructed HREPs with sheet pile cells include the following:

Lake Chautauqua HREP, LaGrange Pool, IWW RM 124.0-129.5, Mason Co., IL, MVR
Swan Lake HREP, Alton Pool, IWW RM 5.0-13.0, Calhoun Co., IL, MVS

MVR – Rock Island District; MVS – St. Louis District; MVP – St. Paul District

c. References

EM 385-1-1, Safety – Safety and Health Requirements, CESO-ZA, 03 Nov 2003

EM 1110-2-2100, Stability Analysis of Concrete Structures, CECW-CE, 01 Dec 2005

EM 1110-2-2104, Engineering and Design – Strength Design for Reinforced Concrete Hydraulic Structures, CECW-ED, 30 Jun 1992 (original), 20 Aug 2003 (Change 1)

E. LESSONS LEARNED (location is in the MVR unless otherwise specified)

Topic	Location	Lesson Learned
Botulism	Lake Chautauqua	Chautauqua experienced botulism deaths of many migratory waterfowl (waterfowl mortalities in 1997 through 2000 were 8,000, 2,500, 250 and 900). Sick birds generally appear in late August when there are low water levels (2 to 10”), low precipitation, and high temperatures for extended periods. These conditions set the stage for the botulism organisms to start reproducing. Birds pick up the toxin and die. Flies lay eggs on the carcasses and the maggots concentrate the toxin to the point where only 3 maggots will kill a duck. The botulism problem usually subsides after the first killing frost. Drying the lake bottom would force the birds to go elsewhere and therefore, avoid the botulism toxins. Therefore, the lower lake dewatering channels were extended from the pump station to the stoplog structure. This required dredging a shallow channel 35’ wide and approximately 11,000’ long. The extended channel allows the area to be dewatered completely. This removes the habitat for waterfowl and shorebird use and allows the Site Manager to do complete searches of any remaining small wet areas. If dewatered early enough, the area will produce moist soil plant foods that can be used by waterfowl and other wildlife when re-flooded in the fall. It will also allow the bottom to dry to the point where equipment can be brought into the area to control invasive vegetation such as willow.
Cell Operation	Andalusia Refuge	For HREPs with water control structures requiring operation during inclement weather, granular surfacing should be provided along the perimeter levee to strengthen the surface under adverse conditions.
Cell Operation	Bay Island	The MSMU was not designed to allow independent operation of the cells. The existing water supply berm was raised and a new gatewell structure was installed in the water supply berm. This added height to the water supply berm in combination with the new gatewell structure now allows independent operation of the cells.
Cell Operation	Princeton Refuge	The concrete stoplog structure did not allow for complete drainage of the north cell into the south cell. As a result, 2 CMP stoplog structures were installed along the cross dike to provide water level management between the cells at lower elevations by gravity flow.
Contract Changes	Lake Chautauqua	The first contract (Stage I) was typical low bid and was below the government estimate. The contractor started on the access road. The contract measured fill only for payment. The first problem was the material disappeared into a large soft spot. Following the first problem, the 1993 weather pattern kept river water levels high and delayed the project more than a year. Following the initial flood, there were several follow-on floods that overtopped levees and caused flood related damages and time extensions. As a result, the contractor got into a routine of not doing very much when the weather and river was cooperating. He did collect flood damages and time extensions after several flood events. The contractor was not used to working in the flood plain and had equipment that was not suitable to the material. In 1996, the Government terminated the contract and developed Stage II. Designers formulated the Stage II contract so that the work could be done quickly, under flood conditions, and at minimal risk to the government. Incentives to speed up work included a shorter contract duration, intermediate completion dates, and structured payment clauses so that payment was not made until a feature was stable. For example, levees had to be constructed in sections and progress payments not made until they were seeded and mulched. In addition, the contractor was responsible for incomplete and exposed work and the contract defined a flood as being water above a certain elevation. Everything below that level would not result in a time extension.

Topic	Location	Lesson Learned
Erosion Protection: Levees	Bay Island	Severe erosion along the northwestern edge of the perimeter levee was evident after the Flood of 1993. Approximately 1,070' of the perimeter levee toe eroded due to Clear Creek. Clear Creek is a meandering stream that runs along this portion of the levee. The erosion created a 2 to 3-ft vertical cut into the levee toe. The levee slope was re-graded and riprap was placed from the base of the levee toe to 6' from the edge of the levee crown.
Erosion Protection: Levees	Peoria Lake	The erosion control mats and seeding for erosion control along the levees of Cells B and C were not successful with water level fluctuations, resulting in bank erosion. Traditional riprap was installed in place of these mats at various locations.
Erosion Protection: Pump Station	Andalusia Refuge	Riprap was found to be missing in several areas at the water control structure. However, it was determined that the lack of riprap was not causing any problems.
Erosion Protection: Pump Station	Peoria Lake	Erosion occurred around the concrete pad at the pump station outlet. The Site Manager installed riprap around the concrete pad to help reduce the erosive effects around the pump station outlet.
Erosion Protection: Wells	Potters Marsh	The well outlet was provided with a splash pad; however, following testing of the well, it was evident that additional erosion protection would be necessary. To remedy the erosion, a mixture of slush concrete and riprap was placed around the splash pad.
Gatewell	Spring Lake	The gate position was difficult to read. The Site Manager painted the top of the gate stem bright orange to make its position easier to read. Stoplogs are used in the gated inlet structure during maintenance of the structure. The stoplogs are difficult to remove with a high head against them. To ease removal of the stoplogs, the gate is closed temporarily to allow water levels to equalize on either side of the stoplogs.
Gated Structures	Finger Lakes (St. Paul District)	Design for a wide range of flow conditions if increasing dissolved oxygen levels is desired. The gated conduits that were used at this site were sized to provide up to 50 cubic feet per second (cfs) to each of the downstream Finger Lakes. A Biological Response study that was conducted after the project was constructed indicated that the required winter flow was on the order of 5 cfs or less, about 1/10th the capacity of the conduits. However, recommended summer discharges are on the order of 40 cfs, which is near the maximum flow of the conduit. Furthermore, the Fish and Wildlife Service often flushes the pipes by using their full capacity to clear out small debris from the entrance and outlet channels.
Gated Structure	Lake Chautauqua	Ensure the contract specifications address the responsibility of structure operation during construction. At Chautauqua, nobody (owner/sponsor, USACE or contractor) wanted to take responsibility for gate openings on a water control structure from the ILWW to the upper lake and eventually that indecision was at least in part cause to a complete loss of that existing structure and construction of a new structure.
Guardrails	Swan Lake (St. Paul District)	Fiberglass-reinforced plastic guardrails have been used at some locations (Swan Lake); however, because of ultraviolet deterioration and difficulty in making repairs should these items be damaged during floods, wire rope guardrails are an appropriate alternative (Batchtown, replacement of guardrails at Swan Lake).
High Water Action Plan	Banner Marsh and Lake Chautauqua	Since HREPs are constructed in typically wet and potentially flooded areas, ensure that the hydraulic conditions at the site are clear in the contract specifications so that bidders are fully aware of "normal" conditions. Ensure that the contract specifications include a submittal for a detailed high water action plan. The plan should include procedures for rising high water and for dewatering after a high water event.

Topic	Location	Lesson Learned
Levee Construction	Swan Lake St. Louis District	The perimeter levee was constructed 1995 and 1996 with large (8 cy) clamshell bucket using lake bottom silts and clays. Portions of the berm have settled more than expected, especially in areas were the berm alignment was across lower elevational areas, such as sloughs. A 5 to 10% design overbuild of berms were to account for anticipated settlement. Some of these areas have now settled below the overflow spillway grade, now making them the low point in the system. The project has experienced overtopping at these low areas and has resulted in higher maintenance caused by washing road stone off of the top of the berm. The low spots of the berms are expected to be brought back up to grade in 2006, subject to funding availability.
Levees: Rodent and ATV Control	Andalusia Refuge	Settlement of the levee was discovered due to animal burrowing, unauthorized vehicle use, and scouring and erosion. Trapping has resolved the settlement due to burrowing animals. Unauthorized vehicle use from ATVs and snowmobiles no longer seems to be a problem. The settlement from scouring and erosion also appeared to be corrected.
Levees: Rodents	Spring Lake	Since construction has been completed, muskrat burrowing has caused severe erosion on the side slopes and large sinkholes on the levee crown. As a result, water is flowing between the units. This has caused the refuge manger to be unable to manipulate water levels within individual cells as desired. The problem has also become a safety hazard to vehicles traveling on the levee crowns. Annual inspection and maintenance will continue to assess the muskrat damage. One possible solution would be to lay chain link fence fabric on the levee slope, providing a physical barrier to the muskrats. Another possible solution would be to establish an aggressive eradication program, such as trapping. Some site managers claim that having flatter side slopes, such as 10:1 vertical to horizontal, can help prevent muskrat burrowing.
Level of Protection	Bay Island	The perimeter levee provides a 2-year level of protection. This level of protection should be used only at sites where impacts of frequent flooding are acceptable for project O&M. It was recommended that perimeter levees provide at least a 5-year level of protection. A higher level of protection will decrease the rate of sedimentation within the MSMU, increase controlled management opportunities, and decrease the risk of prolonged flooding when trying to establish desired vegetation.
Level of Protection	Spring Lake	A 2-year level of protection, as provided by the interior levees (or cross dikes) in Upper Spring Lake, should only be used at HREPs where impacts of frequent flooding are acceptable for project operation and maintenance. Flooding in the spring of 1997 caused damage to some of the embankment materials. The 50-year perimeter levee was not overtopped during the floods of 1997, 1999, or 2001, and is considered an appropriate level of protection.
Pump Cavitation	Banner Marsh	The existing pump station structure was modified as part of the HREP to install a new 48" submersible pump. The existing sump was modified and an anti-vortexing plate was installed prior to pump installation. The pump was factory tested but not to the low sump elevation level as specified. After installation, the pump developed a cavitation noise in the sump level operating range during operation of the pump, which has led to complete failure. As a result, heavy rains have caused localized flooding within the MSMU. It may also cause accelerated wear of pump components, thus shortening the expected service life of the pump. The pump was pulled for inspection and measurements with no conclusive findings. The pump was reinstalled with the cavitation noise present and a spare impeller was purchased for replacement in the future. The recommendation has been to continue using the pump as normal. Under normal operation, the 48" submersible pump is a backup that only turns on when the 24" service pump is unable to keep up. The 24" service pump can handle about 90% of the annual MSMU pumping requirements.
Pump Controller Valve	Banner Marsh	The 48" pump controller failed twice. The first failure was due to condensation in the pump controller cabinet, which caused a component in the soft start drive to fail. The condensation was caused when the power was turned off to the entire pump station by opening the main breaker. This made it impossible for the pump controller cabinet heater to function and condensation resulted. The Site Manager was instructed to not turn off the main breaker anymore. No O&M Manual was available at the time to provide instruction for pump operation. The second failure was a different component in the soft start drive, which is believed to have failed due to stress caused from the first failure. Both problems were corrected by replacing the faulty components. If further components of the soft start drive fail, it has been recommended replacing the entire drive, which is only one part of the pump controller.

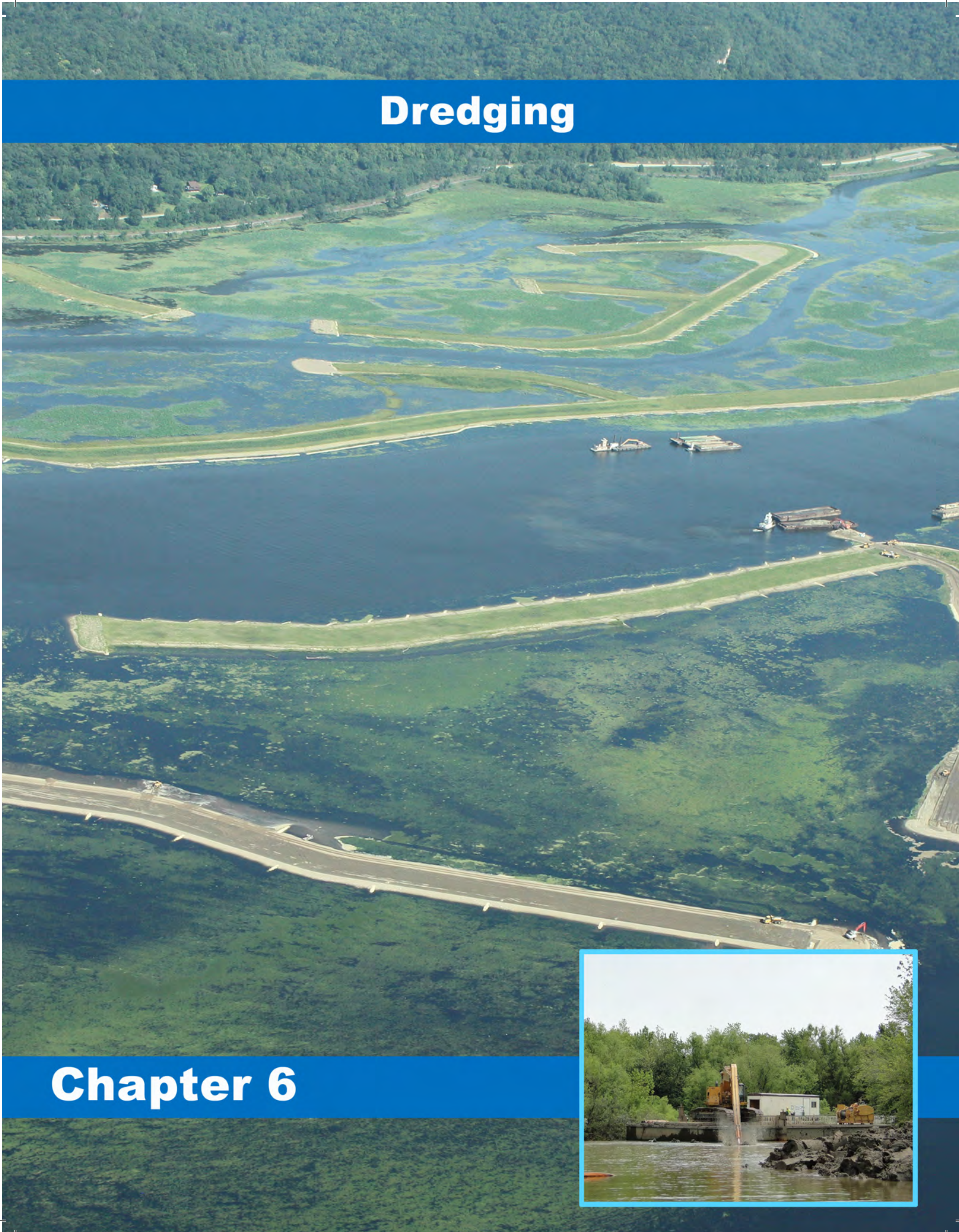
Topic	Location	Lesson Learned
Pump Inspections	Spring Lake	Since the project did not include a system for pump removal, the Site Manager had to add a jib hoist and crane to the pump station to facilitate removal of the pumps for inspections.
Pump Operation	Banner Marsh	A light was installed on the outside of the pump building so that the Site Manager can verify that the pump is running from his house rather than having to drive out to the pump station.
Pump Size and O&M	Lake Chautauqua	Configuration: Lake Chautauqua pump station is a single submersible turbine that pumps from a lower level pump station to the upper level. It is located at the junction of 2 lakes and the river. It is gate controlled and capable of pumping into or out of any of the 3 water bodies or is capable of gravity flow into or out of any of the 3 water bodies. This configuration greatly increases its versatility and also simplifies pump controls. Pump Size: When the pump station was designed, the pump criterion was to dewater the lower lake in 30 days (allows sufficient time for moist soil production). This resulted in a 41,000 GPM pump. Multiple smaller pumps were ruled out as being too expensive. The design criteria were flawed in the following respect: The pump station has never been used to dewater the entire lake within the 30 day timeframe. The cost to run the pump and pay the demand charges is too costly. The FWS refuge staff would rather wait for the river to drop before dewatering mostly by gravity. In fact, waiting is usually faster. (The pump can pump down a full lake by about 0.10' per day). The pump is more than adequate to pump remnants out of the lake and to maintain the lake in a dewatered condition. For these purposes a smaller pump would also work. It would have resulted in less demand and electric charges as well as less submergence requirement and a less expensive pump station. Maintenance and/or repair of pump station components requires the dewatering of the pump station sump area. Pump station component maintenance and repair should be examined for user friendliness.
Pump Station	Andalusia Refuge	When the pump was turned on in the fall of 1994 to fill the MSMU, the trash rack clogged with vegetation and cut off the water supply. Subsequently, a chain link fence was installed 6' from the pump intake, and an outer mesh fence was installed 100' from the pump intake. The outer mesh fence was subjected to damage from ice during the winter of 1995 to 1996. The Site Manager stated that the fences were not working as intended and had been destroyed by ice, and that the vegetation had filled back in from shore to shore. The trash rack fence system had been designed for those years when there was an excess of floating (or dead) vegetation, river levels were low, and fall pumping was required, which didn't meet the needs of the site manager. It was decided that the outer mesh fence could be removed, leaving the posts in place, and re-installed when needed. Otherwise, if the outer mesh fence remains in place, annual maintenance would be necessary prior to ice-over of the refuge.
Pump Station	Swan Lake (lower compartment); Calhoun Point and Stump Lake - MVS	There are permanent pump stations in which the pump is installed in a slanted intake tube supported in the water on the supply side by a system of piles and cross-beams. The discharge pipe passes through the berm (an embankment created between parallel rows of cross-tied sheet piles) and discharges through a duckbill. The pile support system for the pump allows installation without creating a dewatered location for building a sump. The pump support system must accommodate removal of the pump for maintenance.
Pump Station in Cold Weather	Banner Marsh	The pump floatation system would freeze up, so the Site Manager purchased a bubbler system to prevent floats from freezing.
Pump Station Inlet	Princeton Refuge	The river grating on the pump station inlet box has been a challenge. It will plug with debris and create a vortex during pumping operations. It is recommended that a secondary fence be installed between the ends of the wingwalls. This fence would then extend along the top of the wingwalls up to the top of the inlet box to keep debris out during flood events.
Pump Station Inlet	Princeton Refuge	The grating on top of the pump station inlet box is heavy and removing and replacing it for maintenance is dangerous to the operator and hazardous to the public if left off. The grating on top of the pump station inlet box was designed to be heavy for safety reasons and to prevent vandalism. If the grating is replaced with a lighter, hinged section, a padlock should be installed.
Pump Station Location	Princeton Refuge	During construction, the existing pump station was relocated from the downstream end to the middle of the perimeter levee. However, the existing pump station only consisted of a single pump. As a result, a portable pump with a diesel engine mounted on a highway trailer was supplied following construction.

Topic	Location	Lesson Learned
Pump Station Materials	Spring Lake	The door to the pump station rusted on the inside due to moisture. All metal should be galvanized to help prevent rust damage.
Pump Station Siltation	Bay Island	The pump station had a continuous problem with the pumping chamber and intake structure filling in with 2 to 3' of silt. The silt enveloped the pump impellers, thus making the pump station inoperable until the pumping chamber was cleaned out. In addition, removal of the silt in the pumping chamber had been labor intensive and difficult to complete without easy access to the pumping chamber and intake structure. Silt accumulation in the pumping chamber and around the pump impellers created different power demands on the pump motor. Fluctuation in the pump motor loads or possibly incoming power supply had been throwing the phase converter out of balance. The services of an electrical contractor to recalibrate the phase converter had been needed about twice annually since the pump station had been in service. A sluice gate was installed on the outside of the pump station intake structure and that a platform structure was constructed in the pumping chamber. The sluice gate was placed at the intake of the pump station near the existing trash rack. This gate is closed during non-pumping times to prevent the buildup of silt in the pumping chamber. A platform structure with a ladder was installed to facilitate cleaning out of any silt that collects inside the pumping chamber.
Pump Station Stoplogs	Andalusia Refuge	The pump station stop logs would not seal due to the presence of construction debris in the channels. Therefore, the stop log channels had to be cleaned out. Additionally, the stop logs were difficult to remove because of their close proximity to the trash rack. As a result, the pump station trash rack was relocated and a hoist installed.
Pumps and Fishing Lines	Princeton Refuge	Fishing line has been a challenge with the seals around the pump impeller head. A trash rack cleaning apparatus could be utilized to help with the fishing line. This apparatus would have to be used on a regular basis and could be stored in the pump station engine building.
Sheetpile Cells	Lake Chautauqua	The project constructed 4 each 74-ft diameter sheet pile cells. The sheet pile was driven to bedrock and filled with stone. The 4 large cells were connected with arc cells to a lower elevation that would allow complete dewatering of the lake. The arc cells were filled with stone and capped with an H pile supported concrete cap that supported a flood wall and a 10-ft by 10-ft heavy duty sluice gate. The main cells included bridges to span the arc cells and provide access to open and close the gates. The bridge abutments were supported on H-piles driven within the main cells. The gates had back-up bulkheads and aluminum stop logs. **BACKGROUND:** The upper lake at Lake Chautauqua had a 60 year old water control structure consisting or 4 radial gates 12' wide. The gate had not been used for over 30 years. During a flood event, the structure washed out, leaving a large scour hole in the levee system. A flood damage report analyzed various closure alternatives to allow rapid inflow before an over-top event could damage the levee. Other desirable design features were maintaining a consistent water level and increasing the ability to dewater the lake. Analysis showed that another gated concrete structure would be very expensive. Other alternatives included spillways, fuse plug spillway, culverts with gate control, and the selected alternative described below. This design worked well to close the breach in the levee, meet all functional purposes, minimize maintenance, and ease operation. Downstream scour is not a concern and the cost of a stilling basin was eliminated. Used sheet pile was utilized from St Louis District saving additional money. Hydraulics developed an operating plan for when to open the gates. To date the gate plan has worked well and has been used twice. During construction, Engineering used State Plane Coordinates to locate the next main cell after the first cell was constructed and surveyed. Cell spacing was critical so that the gates and floodwall would fit properly. During the gate construction contract, the contractor was required to work up to a designated flood level. He was able to do this by leaving the arc cells extended to the flood elevation and providing interior supports. This worked well and allowed construction within the arc cells during relatively high river levels.
Spillway	Princeton Refuge	During the Flood of 2001, the granular surfacing along the overflow spillway was washed to the downstream slope and the geotextile fabric beneath the granular surfacing had been shifted to the downstream shoulder. Despite the disturbance to the granular surfacing and geotextile fabric, the overflow spillway slopes were still intact with most of the vegetation remaining. It appeared that the geotextile fabric had acted as a slippage plane during the flood event for the granular surfacing to "peel" off the overflow spillway. Therefore, the geotextile fabric was not replaced when the overflow spillway was lowered 8".

Topic	Location	Lesson Learned
Spillway	Princeton Refuge	The design for the overflow spillway was to be 2' lower than the north perimeter levee to allow for rapid filling of the MSMU interior water surfaces prior to overtopping of the perimeter levee. The as-built construction drawings show the final grade of the north perimeter levee at elevation 582.3' msl and the overflow spillway at elevation 580.3' msl, which provides the required 2-ft difference. However, 8" (minimum) of granular surfacing was then placed on the overflow spillway. This would place the top of the overflow spillway at approximately elevation 581' msl. A land survey verified that this was indeed the case. The average top elevation of the north perimeter levee was found to be 582.45' msl, while the overflow spillway showed an average top elevation of 581.05' msl. The result was a 1.4-ft difference between the 2 ends rather than the required 2-ft difference. This discrepancy may have contributed to a large breach in the north perimeter levee during the Flood of 2001. During the flood event, the Site Manager observed that the north perimeter levee and overflow spillway overtopped at the same time, rather than the latter first. As a result, the overflow spillway was lowered 8".
Spillway	Stump Lake St. Louis District	The exterior perimeter berm (levee) was designed with a 200 ft long overflow spillway on the downstream portion of the project. The riprap stone was graded stone C (400 lb top size). Severe erosion to the spillway and adjacent berm occurred during an overtopping event in 1997. In 1998, the spillway capacity was reanalyzed and redesigned with larger riprap stone (1,200 lb top size) and 500' additional length. To date the spillway has been overtopped numerous times and has maintained its integrity.
Spillway vs Stoplogs	Bay Island	Overflow spillways were constructed within each cell to allow the MSMU to flood at a set elevation. The overflow spillways help remove the burden of constantly monitoring the river for rising elevations and the need to access the site for removal of all the stoplogs. After the overflow spillways were installed, it was noted that the transition from the perimeter levee crest down to the overflow spillway crest, a 1-ft vertical drop, may be too abrupt at a 10% slope.
Stoplog Materials	Banner Marsh	One of the stoplog structures is starting to rust due to the high acidity of the water in the project area or it may be a natural occurrence. The Site Manager may need to repaint this structure.
Stoplog Operation	Banner Marsh	The stoplog structures have been difficult to operate. The Site Manager has recommended that the stoplog structures have a sluice gate installed to stop flow. This would facilitate placement and removal of stoplogs.
Stoplog Operation	Banner Marsh	In the other stoplog structure, the stoplogs have a tendency to float. The Site Manager has wedged objects between the C-frame and the end of the stoplogs as a remedial effort to keep the stoplogs from floating. It has been recommended that the stoplog structures have locking mechanisms installed to prevent the stoplogs from floating or the procedure for installing the stoplogs needs to be changed.
Stoplog Operation	Bay Island	The water control structures were designed and constructed with the intention of one person removing and replacing the stoplogs. Stoplogs were constructed out of pressure treated Spruce-Pine with a dimensional size of 5'-2½" x 5½" x 2½". However, removal of the wood stoplogs has proven to be more than a one person operation and can often be a struggle for two persons. It was recommended that the wood stoplogs be replaced with aluminum stoplogs, which are lighter. It was also recommended that one of the bays at each structure be converted to a sluice gate, thereby eliminating some of the stoplogs.
Stoplog Operation	Peoria Lake	The Site Manager has expressed the inability to independently operate the 3 cells, which is undesirable. In addition, there have been challenges in operating the stoplog structures due to the weight of the wood stoplogs. Using solid plates or aluminum stoplogs in lieu of wood stoplogs has been discussed.
Stoplog Operation	Spring Lake	Removal of the stoplogs underwater had been difficult. Locating the lifting lugs with the lifting device was a hit-and-miss operation. Therefore, the stoplog lifting device was modified by the Site Manager to make locating the lifting lugs easier. In addition, the stoplogs do not seal well, allowing seepage between cells. The stoplogs will eventually seal after several days due to fine sediment build-up between the gaps. It has been recommended that the stoplog settings not be changed frequently to avoid breaking this seal. If a more immediate seal is needed, it has been suggested to utilize cinders on the upstream side of the stoplogs.

Topic	Location	Lesson Learned
Vegetation Control (interior)	Andalusia Refuge	An abundance of woody vegetation was also reported on several islands in the MSMU. In 1996, the ILDNR Site Manager aerially sprayed the MSMU to control bulrush, lotus, and willow growth. The islands were also burned in 1997 and 1998 to control undesirable vegetation. A beaver dam was found across the main channel. A continual problem in the MSMU is the erosion of the island banks.
Vegetation Control (levees)	Andalusia Refuge	In 1997 and 1998, thick woody vegetation was noted as growing among the riprap on the perimeter of the levee. The vegetation was removed and the riprap was sprayed with Round-Up. This process has since been repeated several times.
Vegetation Response on Berms	Andalusia Refuge	The perimeter levee was originally seeded with a mixture which was predominantly Indian grass. Initial establishment was successful, however, there was no post-Flood of 1993 re-establishment of the Indian grass on the side slopes of the perimeter levee, nor was the perimeter levee re-seeded. Reed canary grass is now the predominant species. As reed canary grass is very invasive, spraying or controlled burns in the MSMU may be necessary to limit it to the perimeter levee only.
Wells	Fox Island	Test bore holes for new well construction failed to identify large cobble and rocks at approximately the 30-ft depth at both new well locations approximately 1 RM apart. Cost and time escalation was realized and well installation methods were changed dramatically upon the discovery of the cobble.

Dredging

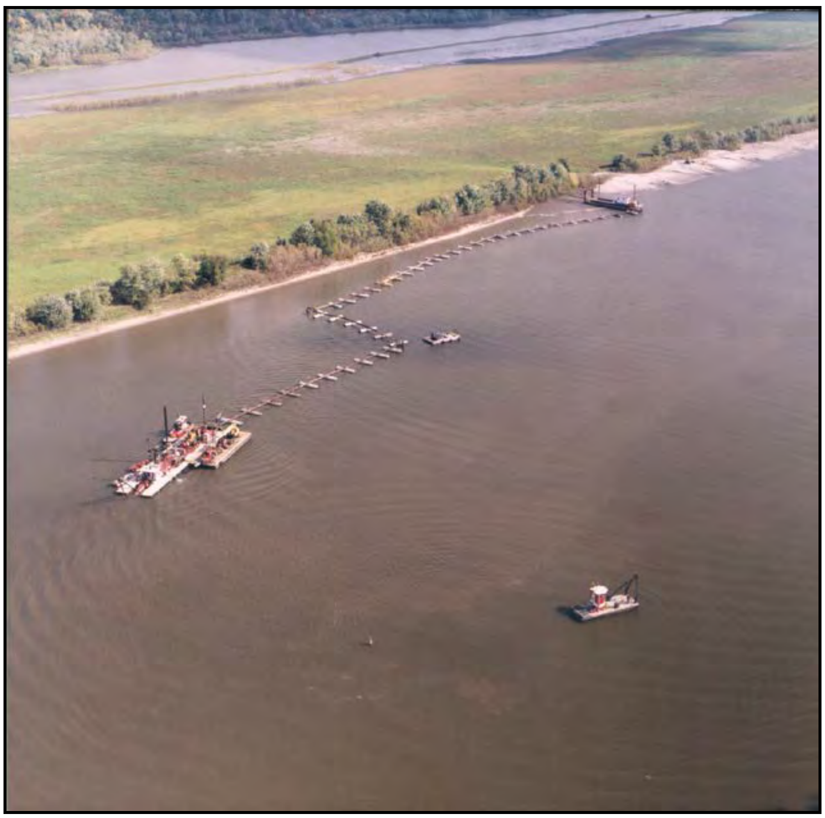


Chapter 6

UPPER MISSISSIPPI RIVER RESTORATION
ENVIRONMENTAL MANAGEMENT PROGRAM
ENVIRONMENTAL DESIGN HANDBOOK

CHAPTER 6

DREDGING



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CHAPTER 6

DREDGING

A. RESOURCE PROBLEM AND OPPORTUNITIES

Large river ecosystems support a variety of habitats, of which, backwaters are an integral component. Backwater habitats support many popular sport fishes, waterfowl, shorebirds, and wading birds. Backwaters are also quiet areas off the main channel where people and animals alike can seek refuge.

Because of the widespread loss of backwater and secondary channel depth and depth diversity due to the high rates of sediment, fish habitat quality has decreased, especially in the winter when such areas provide refuge from harsh conditions in main channel areas.

Many Upper Mississippi River System (UMRS) backwaters have been degraded by excessive amounts of sediment emanating from the basin, tributaries, and mainstem sources. This degradation is in the form of loss of depth, poor sediment quality, poor water quality, and sediment resuspension that blocks light required by aquatic plants.

Backwater sedimentation and loss is especially pronounced in lower pools of the Illinois River where sediment from the row crop dominated landscape continues to be excessive. Streambank erosion throughout the basin is another important source of sediment that fills the backwaters.

One solution to this degradation problem is backwater dredging. Backwater dredging typically consists of dredging channels with fingers (dredged channels that extend out away from the main dredge cut). The depth and size (length and width) of the dredge cut depends on several site specific factors.

The sediment dredged to create depth diversity in the backwaters can be used to enhance aquatic areas with islands or terrestrial areas with increase topographic diversity, which promotes the growth of mast trees.

B. HABITAT REHABILITATION AND ENHANCEMENT PROJECT OBJECTIVES

Habitat Rehabilitation and Enhancement (HREP) Project features are designed with the intent of meeting specific project objectives. It is important for the design team to have an understanding of the relationship between project features and objectives to help maximum benefits and minimize costs. Also, some of the effects of dredging occur secondarily to the obvious primary effects; understanding these relationships even at a basic level can help inform design decisions.

Table 6-1 shows examples of non-specific objectives for HREPs categorized by Essential Ecosystem Characteristics (EECs). For actual projects, these objectives would be more focused, but they are useful here to provide a basic understanding of how project features can be used to meet multiple objectives. The EECs - hydraulics and hydrology, geomorphology, biogeochemistry, habitat, and biota - and some of the objectives that can be addressed with each are briefly discussed. It should be noted that this is not an all-inclusive list, but it is being used here to facilitate consideration of the numerous relationships between features and objectives.

1. Hydraulics and Hydrology. Dredging generally does not directly affect hydrology or hydraulics, other than by increasing the volume of water in the dredged area; however, features such as islands built with dredged material can contribute to this category of objectives indirectly.

2. Geomorphology. Typically the primary purpose for including dredging in HREPs as a stand-alone feature (self-justified) is the restoration of depth in backwaters. Secondarily, the dredged material can be used to improve upland topographic diversity and for the creation of islands. Typically, dredging is included as a means of obtaining material for a dual purpose of island creation and for the restoration of depths in backwaters. Dredging depth is an important considering in meeting HREP objectives. Often, a depth of 6 feet is considered a minimum, but this varies depending on sedimentation rates and target species.

3. Biogeochemistry. Dredging can indirectly affect biogeochemistry by increasing water depths (volume), which in turn can help maintain adequate dissolved oxygen levels especially in winter. The maintenance of oxygenated water below the ice in late winter is a critical consideration. If dredging occurs in highly vegetated areas, the loss of that vegetation would result in some effects to nutrient processing and dissolved oxygen levels, but this is typically of secondary importance.

4. Habitat. Dredging affects habitat directly and indirectly, and is nearly always used in conjunction with a plan to also create or raise islands to meet multiple objectives. The increase in backwater depths, typically to depths of 6 feet or greater, would improve habitat for backwater fishes such as centrarchids and is typically the primary objective for dredging. Dredging in secondary channel can improve habitat for more riverine species, and the dredging of access channel for construction can help meet some side-channel restoration objectives incidentally. However, access dredging and even backwater dredging could be counter-productive if the area dredged contains important habitat/species such as mussels, and such impacts must be considered.

5. Biota. Dredging (and most features used in HREPs) indirectly affect biota through other effects to hydrology, geomorphology, biogeochemistry, and habitat. The effects to biota are seldom measurable in a manner that can clearly prove a cause and effect relationship with project features, so they are often assumed to correlate with physical habitat objectives.

Table 6-1. UMRS Ecosystem Restoration Objectives Organized By Essential Ecosystem Characteristics
(hydraulics & hydrology, biogeochemistry, geomorphology, habitat, and biota in four floodplain reaches)

Upper Impounded Floodplain Reach	Lower Impounded Floodplain Reach	Unimpounded Floodplain Reach	Illinois River
HYDRAULICS & HYDROLOGY: Manage for a More Natural Hydrologic Regime			
A more natural stage hydrograph	A more natural stage hydrograph		A more natural stage hydrograph
Restored hydraulic connectivity		Restored hydraulic connectivity	
	Naturalize the hydrologic regime of tributaries		
	Increase storage & conveyance of flood water on the floodplain		
BIOGEOCHEMISTRY: Manage for Processes That Input, Transport, Assimilate, & Output Material Within UMR Basin River Floodplains: e.g., Water Quality, Sediments, & Nutrients			
Improved water clarity	Increased water clarity		
Reduced nutrient loading	Reduced nutrient loading from tributaries to rivers		
Reduced sediment loading from tributaries & sediment resuspension in & loading to backwaters	Reduced sediment loading & sediment resuspension in backwaters		Reduced sediment loading & sediment resuspension in backwaters. **NOTE:** There are several objectives dealing with tributary loading
Reduced contaminants loading & remobilization of in-place pollutants			
		Water quality conditions sufficient to support native aquatic biota & designated uses	Water quality conditions sufficient to support aquatic biota
GEOMORPHOLOGY: Manage for Processes That Shape a Physically Diverse & Dynamic River Floodplain System			
Restore rapids			
	Restored backwater areas		Restored backwaters
	Restored lower tributary valleys		
Restore a sediment transport regime so that transport, deposition, & erosion rates & geomorphic patterns are within acceptable limits	Restored bathymetric diversity, & flow variability in secondary channels, islands, sand bars, shoals & mudflats	Restored bathymetric diversity, & flow variability in secondary channels, islands, sand bars, shoals & mudflats	Restored secondary channels & islands
	Restored floodplain topographic diversity		
			Restored lateral hydraulic connectivity

Table 6-1. UMRS Ecosystem Restoration Objectives Organized By Essential Ecosystem Characteristics (hydraulics & hydrology, biogeochemistry, geomorphology, habitat, and biota in four floodplain reaches)

Upper Impounded Floodplain Reach	Lower Impounded Floodplain Reach	Unimpounded Floodplain Reach	Illinois River
HABITAT: Manage for a Diverse & Dynamic Pattern of Habitats to Support Native Biota			
Restored habitat connectivity	Restored habitat connectivity		Restored habitat connectivity
Restored riparian habitat	Restored riparian habitat	Restored riparian habitat	
Restored aquatic off-channel areas		Increase the extent & number of sand bars, mud flats, gravel bars, islands, & side channels towards a more historic abundance & distribution.	
Restored terrestrial floodplain areas			
Restored channel areas			
	Diverse & abundant native aquatic vegetation communities (SAV, EAV, RFV)		
		Restored large contiguous patches of native plant communities to provide a corridor along the UMR	Restored floodplain areas
		Restored floodplain wetland areas	
		Restored degraded & rare native habitats	
			Restored lower tributary valleys
BIOTA: Manage for Viable Populations of Native Species Within Diverse Plant & Animal Communities			
Diverse & abundant native aquatic vegetation communities (SAV, EAV, R/F)			
Diverse & abundant native floodplain forest & prairie communities			
Diverse & abundant native fish community		Diverse & abundant native fish community	
Diverse & abundant native mussel community			
Diverse & abundant native bird community			
	Restored diversity & extent of native communities throughout their range in the UMRS	Viable populations of native species throughout their range in the UMRS at levels of abundance in keeping with their biotic potential	Viable populations of native species throughout their range in the UMRS at levels of abundance in keeping with their biotic potential
	Reduced adverse effects of invasive species	Reduced adverse effects of invasive species	
			Restored diversity & extent of native communities throughout their range in the UMRS

C. DREDGING FOR ENVIRONMENTAL RESTORATION

1. Design Considerations

a. Sedimentation Rates. Sedimentation rates are used to calculate the actual depth of dredging required for the project. Biologists usually provide a depth of water needed to achieve a suitable habitat, either for aquatic vegetation or fish habitat. The depth of dredging is found by taking this provided depth and adding on the expected sediment that will settle in the dredge cut over the life of the project.

Historically, determination of sedimentation rates has been based on sound engineering judgment and the best data available at the time. The EMP LTRM effort estimated sediment deposition rates in trend pools based on transects that were established and the re-surveyed for a period of years (Rogala et. al. 2003). Another source for sedimentation rates data is the Upper Mississippi River Cumulative Effects Study, which summarizes sedimentation rates from a number of different researchers. Some sampling has been done without recording such information as the climatic conditions when the sample was collected and the coordinates for the sample location. This data helps to look at general trends but cannot be replicated to accurately monitor sedimentation rates over time.

Sediment deposition studies that have been done on the Upper Mississippi River include Claflin, 1977; Eckblad et al., 1977; McHenry et al. 1984; and Korschgen et al., 1987. Rogala et al. (2003) measured sediment deposition rates in Pools 4, 8, and 13, which are EMP-LTRM trend pools. Poolwide mean rates of 0.04 cm/yr, 0.27 cm/yr, and 0.52 cm/yr were obtained in pools 4, 8, and 13 respectively. They investigated the variation of sediment deposition over time and with bottom elevation along transects. Their results were lower than those obtained by previous investigators, which they attributed to either a less biased site selection than previous studies, a decrease in sediment deposition over time, or an unexplained low rate of deposition during their five year study period.

Sedimentation rate estimates will need to be analyzed on a site by site basis using the most recent data available, ideally from the project site or at least from sites with similar features. Table 6-2 lists calculated sedimentation rates for various EMP projects along the Mississippi and Illinois Rivers. Comparing the higher sedimentation rates shown in the table with those obtained by Rogala et al. (2003) reflect the fact that most of these projects are well downstream of Pools 4, 8, and 13, and sediment loads and deposition rates are higher in these downstream reaches. It may also reflect the fact that HREP projects are often correlated with areas that have high sedimentation rates.

When calculating sedimentation rates for a project, it is important to account for flood events. Flood events drastically increase the sediment delivery of any river and therefore can skew a sedimentation rate that has been calculated for any time frame. Pre-project monitoring, for example, a sediment gage or cross-sectional surveys also aid in the development of an accurate sedimentation rate.

Furthermore, a newly dredged channel in the backwater can act like a sediment trap until it reaches an undeterminable equilibrium. Therefore, in post-project monitoring, the sedimentation rates calculated may be higher than previously estimated. Once the channel and sediment load reaches equilibrium, the sedimentation rate should decrease.

Table 6-2. Sedimentation Rates for Various EMP Projects on the Mississippi River

Site	River Mile	Years From Which Avg Rate Was Determined	Avg Sedimentation Rate (DPR) (in/yr) [1]	Date Project Completed
Andalusia	463.0-462.0	1936-1987	0.50	09-1994
Bertom McCartney Lakes	602.8-599.0	1938-1988	0.39	10-1991
Big Timber	445.0-443.0	1938-1988	0.51	10-1994
Brown’s Lake	546.0-544.0	1930-1987	0.45	09-1990
Cottonwood Island	331.0-328.5	1938-1994	0.46	05-2000
Lake Odessa	434.5-441.5	1950-1995	.39-.79	
Long Island (Gardner) Div	340.2-332.5	N/A	0.21	09-2004
Lake Onalaska	702.5-704.0	1937-1986	0.35	10-1989
Bussey Lake	616.2-617.2	1935- 1987	0.31	06-1996
Indian Slough	760 - 758		Not available	
Peoria Lake	181.0-162.0	N/A	1.5	10-1996
Pool 11 Islands	592.0-583.0	1938-1950 1951-1995	0.61 0.13	07-2005
Potters Marsh	526.0-522.5	1938-1990	0.25	12-1995

[1] DPR - Definite Project Report, a planning document for EMP projects

b. Dredge Method. There are two basic categories of dredges, mechanical and hydraulic. Both types of dredges are designed to maximize the quantity of material dredged. While selecting dredge equipment for a project, it should be noted that most dredges are not well suited to efficiently work within small tolerances such as ± 0.1 feet in elevation or in maintaining very specific side slopes.

In addition to mechanical and hydraulic dredges, there are many more sub-types of dredge equipment and dredging techniques. A sub-type of dredge equipment discussed in this chapter is the floating excavator. A floating excavator is ideal for use in marsh-like areas. A more recent dredging technique that is being more widely used is high solids dredging such as Dry DREdge™. This technique can be used for the filling of geotubes or for any type of dredging where there are water quality concerns.

i. Mechanical Dredging. Mechanical dredges typically include backhoe, clamshell, and dragline. Figure 6-1 shows a schematic of a mechanical dredge as well as a picture of a clamshell bucket.

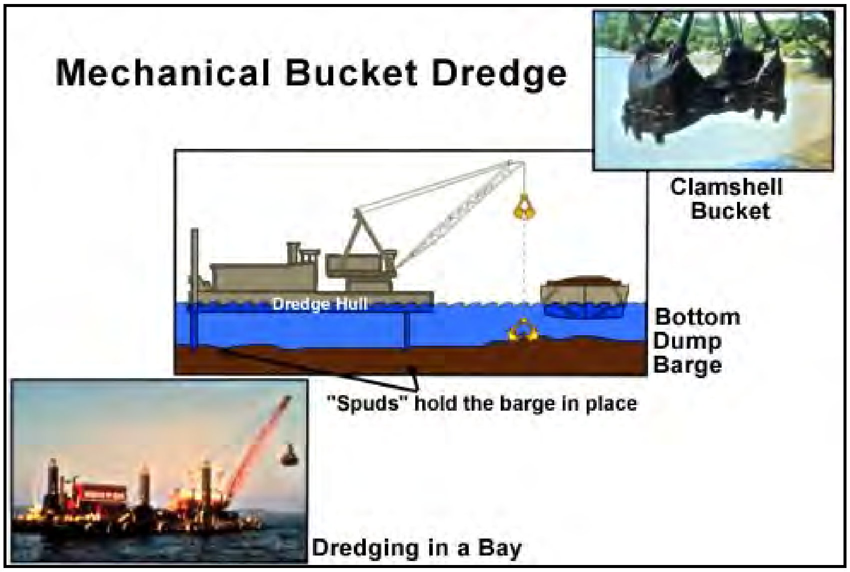


Figure 6-1. Clamshell Dredge

Mechanical dredges are capable of dredging hard packed material and also have the ability to remove debris. For the most part, these type of dredges can work in relatively tight areas and are efficient for side casting material from dredge cut to placement site. Photograph 6-1 shows a clamshell dredge side casting material during the construction of Mud Lake, part of the Pool 11 Islands EMP project. Mechanical dredges are also efficient for transporting material over long haul distances (greater than two miles) and have relatively low mobilization costs. As compared with hydraulic dredging, mechanical dredging does not have the issue of managing return water.

Photograph 6-1. Clamshell Dredge Side Casting Material at Mud Lake, IA

Mechanical dredging generally has lower production rates when compared to hydraulic dredging. It is also difficult to retain fine/loose material in conventional buckets. Mechanical dredging is also inefficient for transporting material over short haul distances (less than two miles), and in areas which contain restricted width access points when barges are used to transport the dredged material. For mechanical dredging in Quincy, IL, barges were used to transport dredged material to the disposal site (photograph 6-2).

Photograph 6-2. Mechanical Dredging in Quincy Bay Harbor Quincy, IL

ii. Hydraulic Dredging. Hydraulic dredges include cutterhead pipeline, hopper, suction, and dustpan. For ecosystem dredging, the hopper, suction and dustpan dredges have not been typically viable options due to their size and difficulty in maneuvering, although they could be used for some large side channel work or island construction efforts. Therefore, this section will focus on the cutterhead pipeline dredge. Figure 6-2 is a schematic of a cutterhead pipeline dredge as well as a picture of the cutterhead. A cutterhead pipeline dredge is shown on the cover of this chapter.

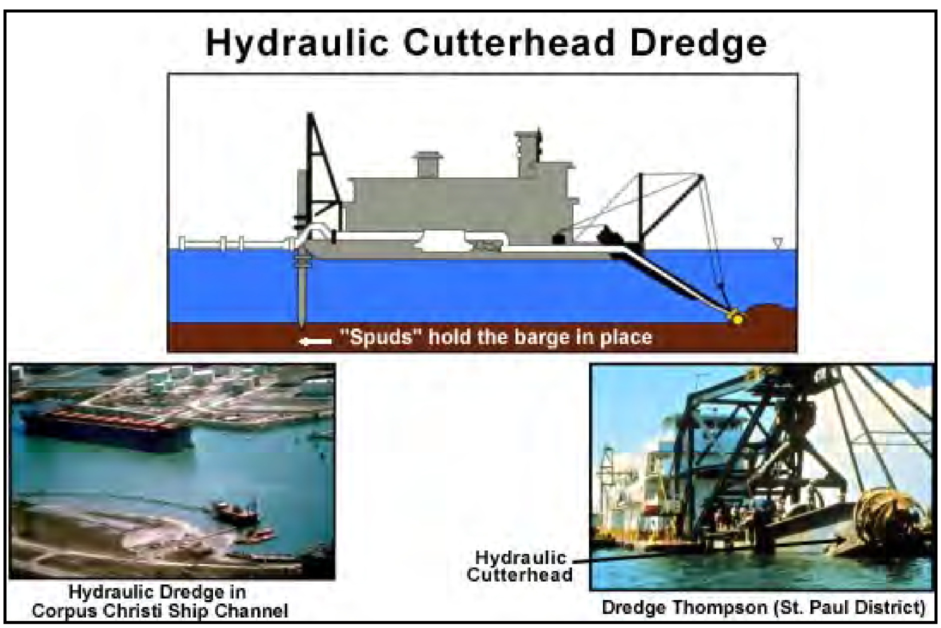


Figure 6-2. Cutterhead Pipeline Dredge

Cutterhead pipeline dredges are sized based on the discharge pipe inside diameter and are typically available from 8-inch to 20-inch with larger applications reaching 36-inches or more. Table 6-3 shows the various EMP projects that have used hydraulic dredging in their construction.

Cutterhead pipeline dredges are capable of excavating most types of material and can even dredge some rock without blasting. Unlike mechanical dredging, hydraulic dredging allows for direct placement of material into a placement site. Hydraulic dredging also allows for the ability to pump almost continuously which results in higher production rates than mechanical dredging. This method is also very cost effective if within economical pumping distances of placement site (less than 2 miles).

Cutterhead pipeline dredges, however, have difficulty with coarse sand in high currents. In general, these types of dredges are sensitive to strong currents. Therefore, provisions should be made in the plans and specifications of any project to allow for down time for dredging in case of flood events. Another provision to put in the specifications is the passage of other motor vessels as the pipelines and/or wires associated with hydraulic dredging may obstruct navigation. Other disadvantages of this type of hydraulic dredging are that cohesive material and debris can block cutterhead which can in turn reduce efficiency. The dredging slurry is 80 to 90 percent water (the other 10 to 20 percent is sediment) which can cause difficulties in obtaining and administering a water quality permit. Since this water has to be returned back to the source, return water management must be incorporated into any design. A minimum of a 5-acre site is recommended for hydraulic dredging in order to settlement of suspended solids from the slurry and leave sufficient room for the stockpiling of material. Photograph 6-3 shows a hydraulic dredging discharge site at the Union Township Levee and Drainage District near La Grange, MO. Lastly, hydraulic dredging also has high mobilization costs when compared to mechanical dredging.

Table 6-3. Hydraulic Dredge Sizes at Various EMP Projects on the Mississippi River

Project	River Mile	Dredge Quantity (cubic yards)	Size of Cutterhead (in.)
Bertom McCartney Lakes	602.8-599.0	400,000	16
Lake Odessa	434.5-441.5		
Lake Onalaska	704-702.5	1,340,000	22
Bussey Lake	617-616	270,000	24
Indian Slough	760-758	46,000	12
Long Island (Gardner) Division	340.2-332.5	83,000	8
Big Timber	445.0-443.0	143,000	8-10
Spring Lake	532-536		22
Brown’s Lake	546.0-544.0	370,000	10-14

Photograph 6-3. Hydraulic Dredging Material Discharge at La Grange, MO

iii. Floating Excavator. A floating excavator as seen in photograph 6-4 below is a normal hydraulic excavator with a different undercarriage that gives the excavator a very low ground pressure. This very low ground pressure allows the excavator to work in marsh/wetland type environments where a normal excavator or typical dredge cannot reach.

Photograph 6-4. Floating Excavator

As stated previously, floating excavators are ideal for those hard to reach places and are highly mobile. However, they are not as efficient as the other types of machines discussed earlier in this chapter.

iv. High Solids Dredging. High solids dredging, also known as Dry DREdge™, is a very useful technique. This technique utilizes mechanical dredging to produce a slurry that is 50 to 80 percent solids, thus resulting in a relatively clean effluent. This technique can be used to fill geotextile containers, which can in turn be used to build form the outer ring of an island. Photograph 6-5 depicts the construction of an island in the Illinois Waterway near Peoria, IL using geotextile containers. High solids dredging is one of the only techniques suitable for building islands out of a highly silty material. This technique can be used when contaminants are present in the sediment.

Photograph 6-5. High Solids Geotextile Containers Placement Peoria, IL

c. Production Rates. Production rates are the amount of material, usually measured in cubic yards (CY), a dredge can remove per unit of time, usually expressed per hour. Production rates are useful to help determine the construction schedule of a project. Production rate estimates should be one of the basic components in determining the length of a construction contract.

When estimating the production rate, research should be done so that the production rate accurately depicts what will occur in the field. The Cost Engineering Dredge Estimating Program is available online from the Walla Walla District at http://www.nww.usace.army.mil/html/offices/ed/c/cedep.asp . The Microsoft Excel spreadsheet allows the user to estimate construction costs, mobilization costs, and production rates based upon variable factors at individual dredging sites using rock pipeline, pipeline, mechanical, and hopper dredging techniques. Table 6-4 lists an estimated production rates for hydraulic dredging.

Table 6-4. Production Rates for Hydraulic Dredges

Dredge Size	Assumed Pump Power	Up to This Length [1]	Hourly Production	At This Length [1]	Hourly Production
10 in	500 HP	2,000 ft	200 cy/hr	4,000 ft	130 cy/hr
12 in	700 HP	2,500 ft	270 cy/hr	5,000 ft	180 cy/hr
14 in	1000 HP	3,000 ft	380 cy/hr	6,000 ft	250 cy/hr
16 in	1300 HP	3,500 ft	500 cy/hr	7,000 ft	330 cy/hr
18 in	1600 HP	4,000 ft	650 cy/hr	8,000 ft	420 cy/hr
20 in	2000 HP	4,000 ft	800 cy/hr	8,000 ft	520 cy/hr
24 in	3000 HP	5,000 ft	1,200 cy/hr	10,000 ft	780 cy/hr
27 in	4000 HP	5,500 ft	1,500 cy/hr	11,000 ft	980 cy/hr
30 in	5200 HP	6,000 ft	1,800 cy/hr	12,000 ft	1,170 cy/hr
32 in	6700 HP	6,000 ft	2,100 cy/hr	12,000 ft	1,370 cy/hr

[1] The pipe length consists of the actual length of pipe from the dredge to the discharge point, plus an equivalent length to allow for the piping on the dredge, for fittings, and for rises in elevation.

d. Dredge Cut Dimensions. Dredge cuts for environmental restoration are very site specific. There are several factors that should be taken into consideration when designing a channel. Some factors are biological concerns, logistics of dredge equipment mobilization, and hydrology and hydraulics.

Determination of the desired dredging depth includes assessment of typical water level elevations, present low-flow winter regulations, desired maintained water depth and projected sedimentation over the project life. Typically, the maintained water depth is determined from the anticipated maximum ice depth and the desired maintained water depth below that ice. Ice depths vary along the Upper Mississippi River, and need to be determined for the proposed HREP location. A desired water depth of 2 to 4 feet below the ice is typically optimal. This translates to a maintained water depth in the four to 6-foot range with 6 feet being a commonly accepted depth. It should be noted however that flow conditions can alter the formation of ice, for example, higher flows does not allow the water to freeze; therefore, a hydraulic analysis should be done to determine what flows will be present and if that flow will allow ice to form.

Caution should be used to avoid dredging to elevations greater than those required to establish the maintained water depth as this could result in the loss of littoral habitat.

Width of the dredge cut will be determined by existing channel conditions, project requirements, placement site capacity, and project funding. Typically, dredge cuts are designed based on a bottom width. Table 6-5 lists various dredge cut dimensions for various EMP projects.

In-depth geotechnical analysis needs to be performed to determine the type of material that is being dredged so that the proper side slopes can be designed. In some cases, the channel has been dredged with vertical side slopes, and the material is allowed to slough to its natural angle of repose. This helps to minimize the project cost by reducing actual dredging time and quantities.

Table 6-5. Dredge Cut Dimensions for Various EMP Projects on the Mississippi River

Project	River Mile	Bottom Width (ft)	Depth Below Flat Pool (ft)	Channel Side Slopes (H:V)
Andalusia	463.0-462.0			2:1
Cottonwood	331.0-328.5			Vertical
Lake Odessa	434.5-441.5	30 30 50	6 6 6	1.5:1 4:1 4:1
Lake Onalaska	704-702.5	100-150	8-15	2:1 3:1
Bussey Lake	617-616	75	6-8	6:1
Indian Slough	760-758	125	5	Ang. Repose
Long Island (Gardner) Division	340.2-332.5	50	7.5	Vertical
Peoria Lake	178.5-181.0	95	7	4:1 & 3:1
Potter's Marsh	526.0-522.5	50	8-10	2:1
Big Timber	445.0-443.0	30-50	4-9	2:1
Brown's Lake	546.0-544.0	30	9	2:1
Pool 11 Islands	592.0-583.0	33	8	3:1

e. Deep Holes. Deep holes are dredged "pockets" of deeper water that provide habitat for fish. Deep holes are typically dredged to a depth of 20 feet below the flat pool elevation and vary greatly in size. Either a mechanical or hydraulic dredge can be used to construct a deep hole, depending on the size. For smaller deep holes, a mechanical dredge should be used as it will be difficult to maneuver the cutterhead on a hydraulic dredge. Special attention should be paid to the sedimentation rates in the area of the deep hole as these cuts have more of a tendency to act like sediment traps.

f. Sediment Basins. A sediment basin consists of an earth embankment or a combination ridge and channel generally constructed across the slope and minor watercourse to form a sediment trap and a water detention basin. Sediment traps can be used to reduce watercourse and gully erosion, trap sediment, reduce and manage onsite and downstream runoff, and improve downstream water quality.

While not expressly precluded under the EMP authorization, Corps policy has generally regarded such features (upland sediment control) as beyond its purview and as the responsibility of other agencies. Nevertheless, two HREPs with upland features, Swan Lake and Batchtown, have been advanced as a result of specific Congressional directives. In both instances, the upland sediment control features were the most cost-effective way of protecting habitat in the project area. These features include hillside retention ponds, terracing, and other measures to reduce sediment delivery to the specific project area, but do not extend to land conservation practices throughout the watershed. Not all sediment basins are constructed in the upland, and could be constructed within floodplains for the purposes of ecosystem restoration.

The Natural Resources Conservation Service (NRCS) has expertise in designing sediment basins, developed through years of helping farmers and landowners to reduce erosion of their land. The NRCS has published two Conservation Practice Standard documents (Codes 350 and 638, 2001) on the design of sediment basins that should be considered during the design of a sediment basin; site specific requirements or project features could be modified based on the site and desired goals for the project.

2. Monitoring the Dredge Cuts. Monitoring of the dredge cuts should start as soon as they are constructed. Monitoring this soon will aid in the determination of the sedimentation rates for the new dredge cut. To maintain consistency, survey monumentation should be coordinated with any individual who could monitor the project. These individuals could include surveyors, hydrologists, fish biologists, etc. The survey monuments should be positioned such that they will be easily used and not deteriorate through the life of the project.

3. Common Problems Associated with Dredging. Most difficulties in dredging do not shut the operation down for long periods of time. The most common problem associated with hydraulic dredging is damaging the cutterhead. Another problem is access into backwater sites. Most problems, except for equipment failures, can be avoided by obtaining as much information about the bathymetry and hydraulics of the site and providing that in the plans and specifications that the contractor will utilize to construct the project.

4. Lessons Learned

- Document assumptions made about production rates estimated during the planning and plans and specifications phase of a project. This documentation will help evaluate a contractor's proposal to construct the project. Also, document the contractor's actual production rate to add to record for future reference.
- Always keep in mind the water quality restrictions on return water. This can drastically alter the method of sediment removal.
- Make sure the contractor is aware of the flooding frequency of the area.
- Layout the schedule of the project such that the likelihood of the contractor mobilizing twice is minimal.
- Dredging is very site specific – each reach of any river has its own characteristics that need to be studied and monitored to achieve a lasting design.
- Estimating the sedimentation rate during planning and plans and specifications phases is vital to the success of the project. If the sedimentation rate is significantly inaccurate, the project may have to be dredged midway through the life of the project at the sponsor's expense.
- Based on material characteristics, if sloughing is anticipated the dredge cut should be widened or stepped to minimize depth and loss as cut sloughs in.
- Inlet channels that are directly perpendicular to the flow path of the main channel typically silt in faster than an inlet channel that is not.
- The use of flexible dredge disposal pipe, most commonly in the form of high density polyethylene, is may be preferred in sites where disturbance to existing conditions must be limited. The pipe is flexible enough to bend and avoid trees and is light enough to be pulled by a single dozer or skid steer.

D. DREDGED MATERIAL PLACEMENT AND USES IN ENVIRONMENTAL RESTORATION

1. Design Considerations. Placement sites for dredged material may be located upland out of the floodway, along the bankline or inwater. They may be confined disposal facilities (CDF) incorporating perimeter berms to confine the dredged material and return water, if applicable, or open sites allowing easy access for placement sites and shaping of the dredged material. A list of potential placement sites that meet project goals and objectives should be developed for evaluation.

Over the years, more efficient and worthwhile uses of dredged material, rather than just storing it on the bankline or in a CDF, have been developed. This trend has greatly impacted the use of dredge material in environmental restoration. Dredged material is now used to build islands, seed islands, build low level of protection levees, and create floodplain depth diversity.

a. Conventional Placement of Dredged Material. Once a list of potential placement sites has been developed, a search of existing databases, maps and other sources should be completed to identify any known issues or concerns. Some possible issues or concerns are:

- impacts to wetlands, endangered species, water quality, aquatic and terrestrial species
- floodway conveyance, flood heights, and flood storage impacts
- existing land uses
- real estate issues
- hazardous, toxic, and radioactive waste concerns
- beneficial uses

b. Restoration Uses for Dredged Material

i. Islands. The main restoration use for dredge material is for island building. This is a very beneficial use because the haul distance from the dredge cut to the island site is usually very minimal. Islands are constructed using both hydraulic and mechanical dredges with material transported from various distances. The longest distances can exceed several miles and involve the use of a booster pumps if being done hydraulically. The shortest distances involve side casting material to build the island. Refer to Chapter 9 of this handbook for more information on island building.

ii. Levee. Dredged material can also be used to build a new levee or strengthen an existing levee as part of a moist soil unit. Attention needs to be paid to the type of material being dredged so that the proper side slopes and compaction requirements are met. This will help ensure stability of the structure. Refer to Chapter 2 of this handbook for more information on levees and moist soil units.

iii. Floodplain Depth Diversity. Dredged material can be placed in a variety of places to increase floodplain depth diversity and habitat. Dredged material can be placed on existing islands, banklines, and uplands. These areas are typically planted with mast trees. Refer to Chapter 8 of this handbook for more information on floodplain restoration.

2. Lessons Learned

- The sediment to be dredged should be thoroughly tested for contaminants. If the tests results show an unacceptable level of contaminants in the sediment, an environmental engineer should be consulted. Presence of contaminants in sediment can severely limit what can be done with that sediment.
- Typical permits required for dredging and dredged material placement include NEPA, CWA section 404(b)(1) compliance, state floodplain permit, section 401 water quality certifications and if applicable, a state floodplain construction permit and CDF permit
- When placing dredged material in and around mature trees, the depth of the material should be minimized so as to not kill the trees

E. Case Studies

1. CHIPPEWA RIVER SEDIMENT TRAP

St. Paul District, Mississippi River (RM 763.4)
Feature Constructed 1984

At the confluence of the Chippewa and Mississippi Rivers, a sediment trap has been maintained by the St. Paul District since 1984. Dredging of the trap averages 120,000 tons per year with the remaining 820,000 tons per year entering the Mississippi River. The contribution of bed material sediment from this tributary is one of the primary reasons 1/3 of the St. Paul District's dredging occurs in Lower Pool 4. Bed and bank erosion accounts for the majority of the sediment being transported.

Lessons Learned

- Because sediment traps tend to trap more sediment than the navigation channel, the overall dredging volumes in this reach of the river have increased since 1984. However, dredging of the trap resulted in significant decreases in dredging at the downstream Reads Landing and Crats Island dredge cuts (76 percent and 26 percent respectively). The reduction in dredging at Reads Landing has significance beyond the amount of material dredged. Prior to 1984, channel closures and emergency dredging were common occurrences at Reads Landing. This resulted in significant delays to the towing industry and environmental concerns regarding the emergency placement of the dredged material. This has been mostly eliminated through maintenance of the sediment trap.
- Although the Chippewa River sediment trap is maintained using O&M funds, it definitely reduces downstream sediment loads. Since sediment deposition is a major concern on the Mississippi River, the benefits the trap has in reducing the downstream sediment load and subsequent sediment transport to backwater areas is a positive impact. Sediment traps such as this could be considered at other tributaries.

2. BROWN'S LAKE HREP (figure 6-3)
Rock Island District, Mississippi River (RM 546.0-544.0)
Contract Number DACW25-88-C-0077
Feature Constructed 1988-1990

- Included construction of deflection levee, a water control structure, improved inlet side channel, side channel excavation, lake dredging, terrestrial dredged material placement, and planting of mast trees (figure 6-3)
- Dredging component included the inlet channel improvement to reorient the mouth downstream to minimize debris and bedload sediment from reaching the new water control structure.
- Performed lake dredging to maintain a minimum water depth of 5 feet below flat pool elevation. 20-foot holes were dredged for diversity.
- Placement site was replanted with mast tree.

Performance. The dredged channels and deeps holes appeared to be filling in at a faster rate than the undisturbed area. Further data collection will continue to define sedimentation rates.

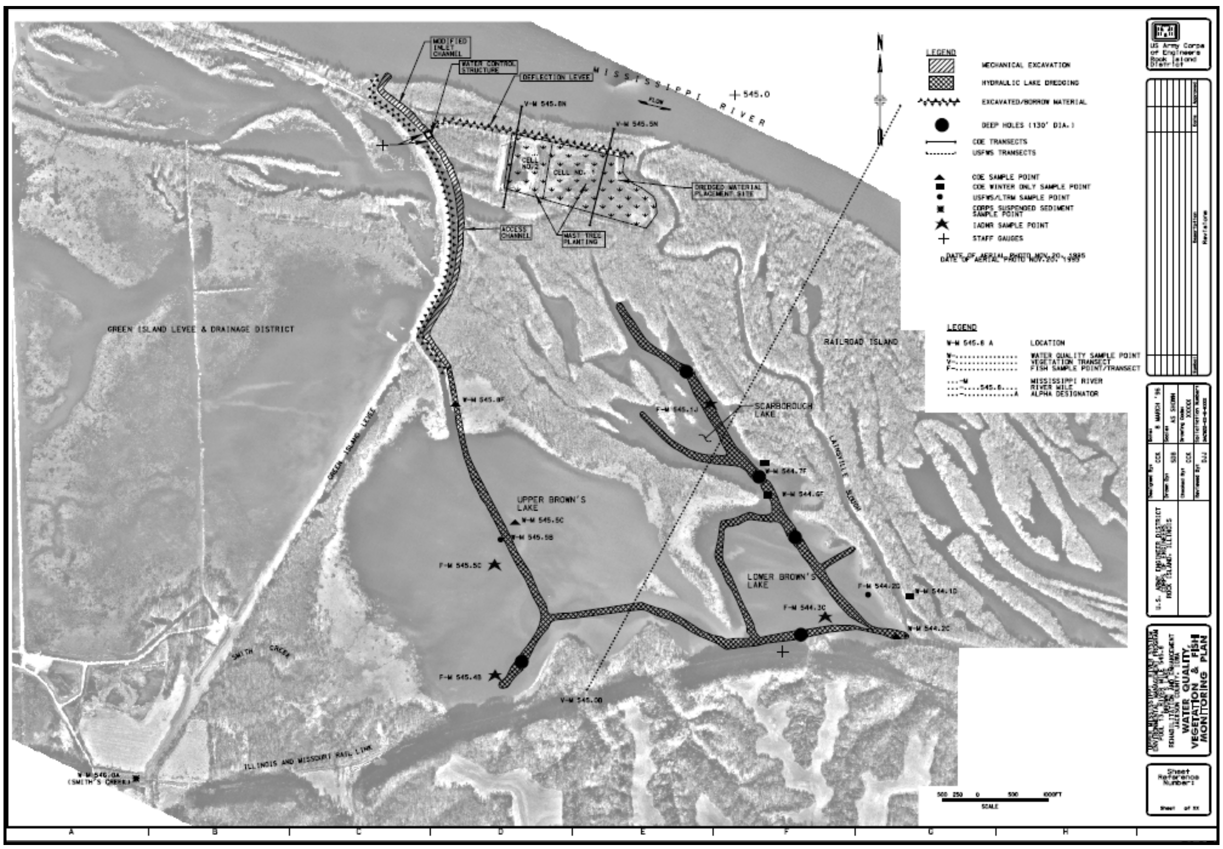


Figure 6-3. Browns Lake HREP Site Plan

3. BERTOM AND MCCARTNEY LAKES
Rock Island District
Mississippi River (RM 602.8-599.0)
Contract Number DACW25-90-C-0020
Feature Constructed 1990-1991

- Incorporated a partial closing structure, fish and mussel rock habitat, and dredging to meet project objectives. Dredging features included deep water habitat, an increase in dissolved oxygen, and a minimum water depth of 6 feet over the project life, with a 10-foot minimum depth adjacent to the railroad tracks (figures 6-4 and 6-5 and photograph 6-7).
- Dredged material was used to build a kidney shaped island with a perched wetland. The island has significant waterfowl use (figure 6-6 and photograph 6-6).

Performance. Currently, the project is meeting its goal of providing deep aquatic habitat volume, but the rate of loss of aquatic habitat volume due to sediment deposition appears to be larger than anticipated based on sediment transects collected in 1993 and 1998. The rate of volume loss has been 3.9 ac-ft/yr versus 1 ac-ft/yr.

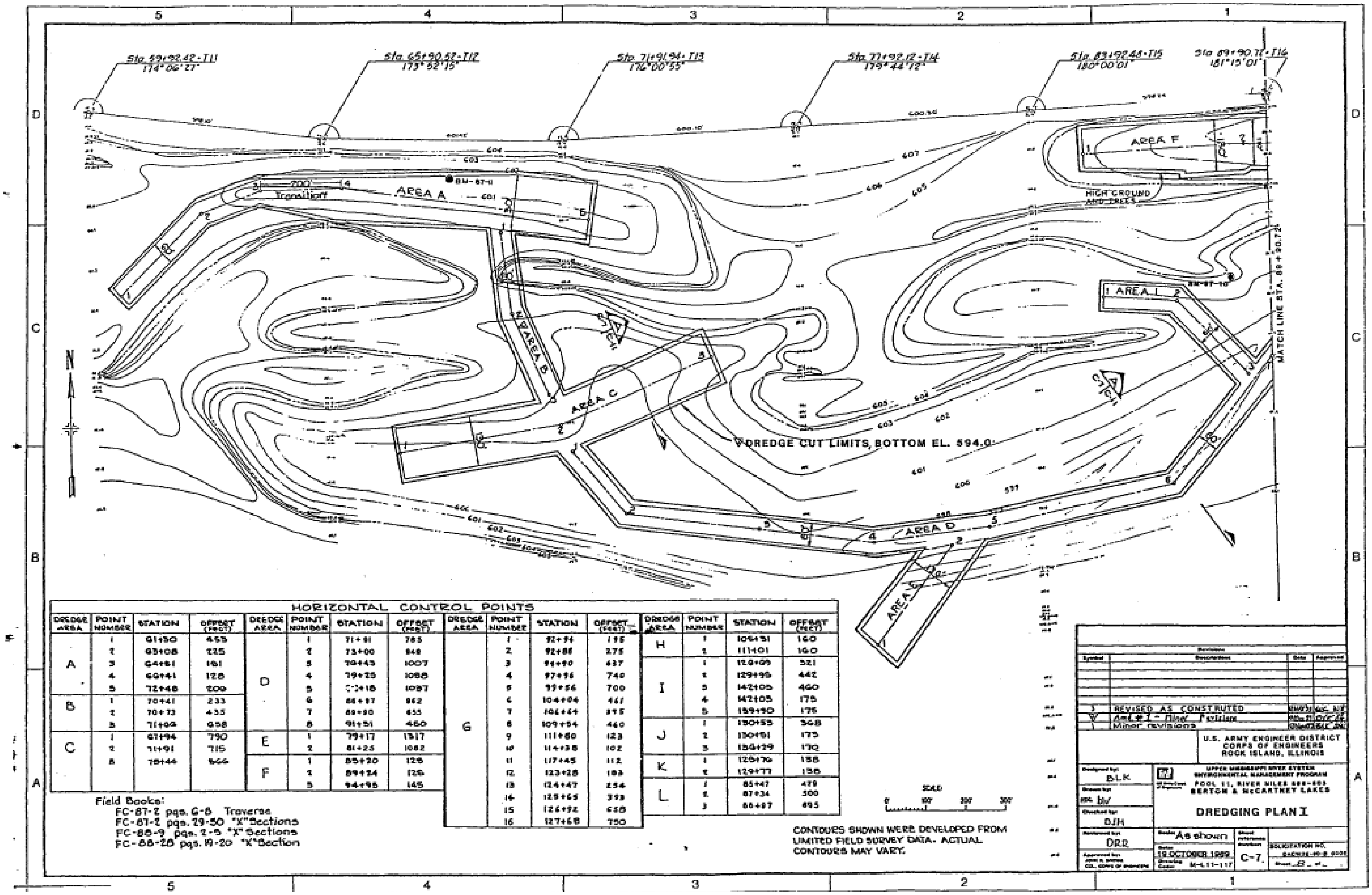


Figure 6-4. Bertom and McCartney Lakes Dredge Areas – Dredging Plan I

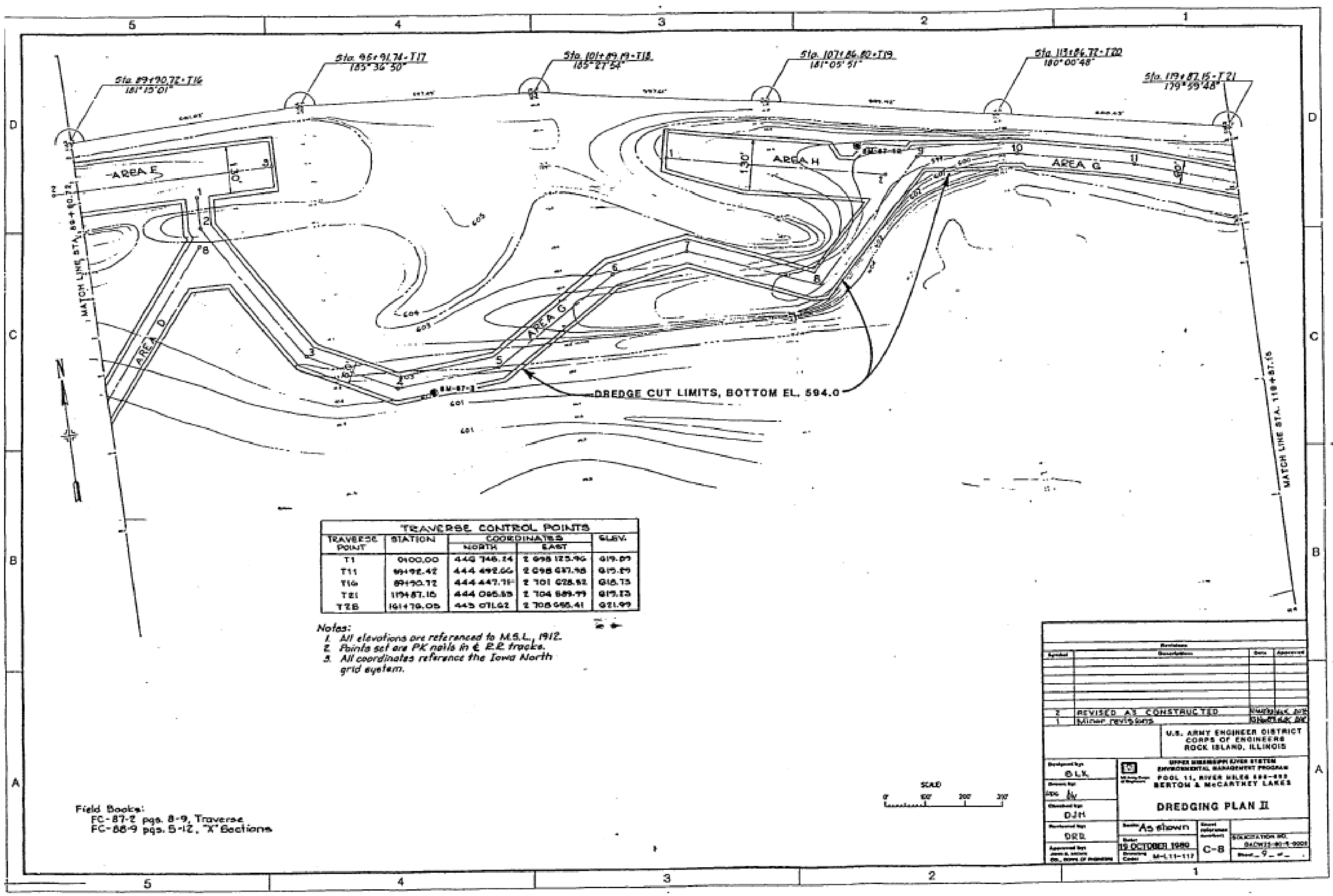


Figure 6-5. Bertom and McCartney Lakes Dredge Area -Dredging Plan II

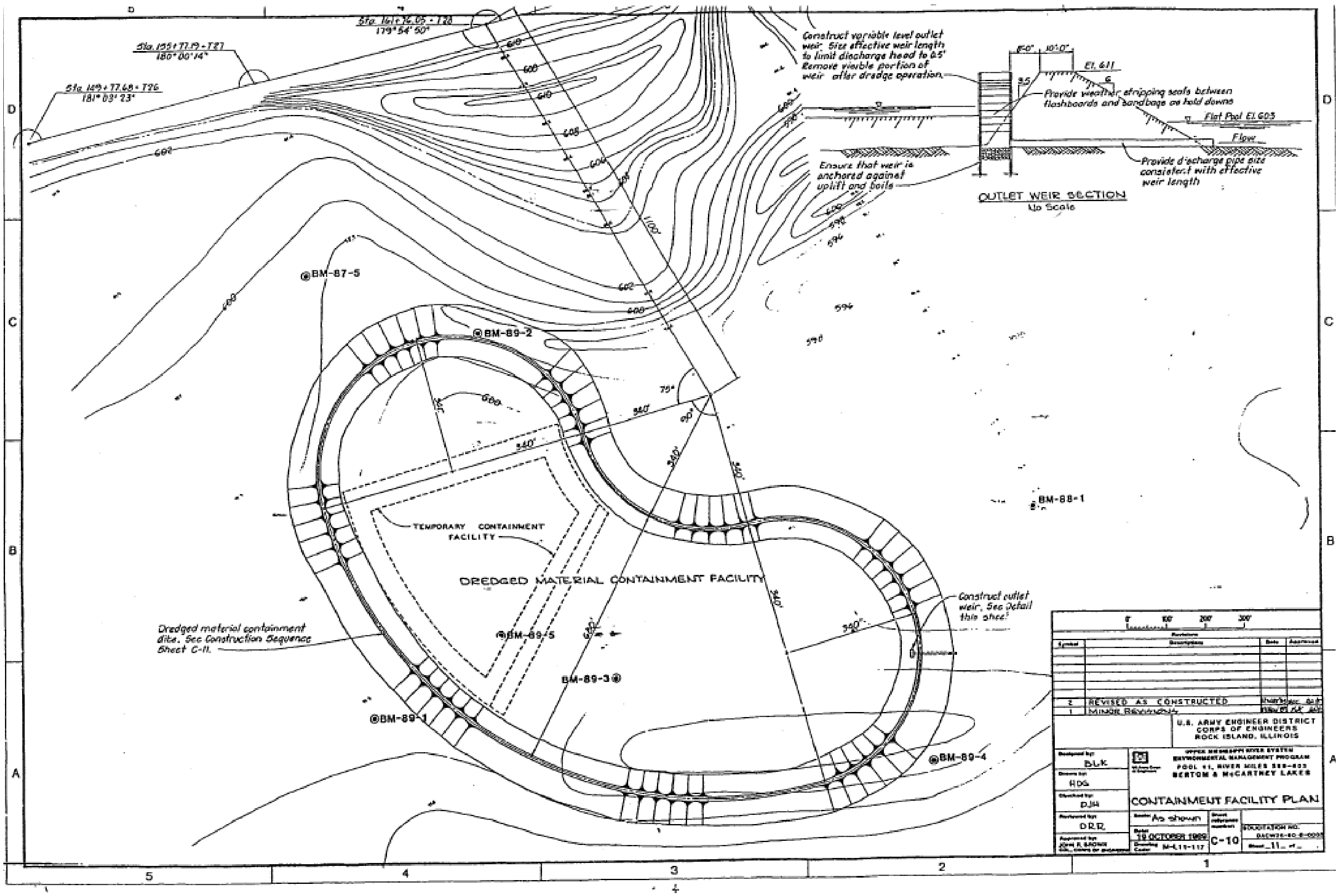


Figure 6-6. Bertom and McCartney Dredged Material Placement Site

Photograph 6-6. Bertom and McCartney View of Dredged Material Placement Site From Nearby Bluff, 8/1992

Photograph 6-7. Bertom and McCartney Aerial View of Dredged Channels, 8/1992

4. LAKE ONALASKA HREP
St. Paul District, Mississippi River (RM 704 – 702.5)
Feature Constructed 1989

- Each channel leg is approximately 7,000 feet long and 100 to 150 feet wide, although some parts of the channels were dredged up to 300 feet wide to gain additional material for highway fill. The majority of the channel bottom was excavated to a depth between 10 and 15 feet, except the lower 1,500 feet of each channel, which was dredged to a depth of 8 to 10 feet (at the low control pool elevation of 639 feet above mean sea level). Greater depths were excavated in a spur that extends toward Halfway Creek, creating a sediment basin at the mouth of the creek (figure 6-7). Additional channels were dredged adjacent to and between the habitat channels in order to supply the additional amount of material required for the Wisconsin DOT highway project. These channels are not considered to be part of the habitat project; however, they do provide increased deepwater habitat benefits to this backwater area.
- Approximately 1,340,000 cy of material was dredged from the channel areas (160,000 cy for islands, 900,000 cy for highway embankment, and 280,000 cy of overburden fine material placed on Rosebud Island). The project was designed with sufficient dredged depths to preclude maintenance dredging during its 50-year life (USACE 1998).

Lessons Learned

- Dredge production was reduced with coarse gravel size alluvium encountered in the dredge cuts.
- Project objectives should include information on the range of variation of important parameters. In this case the dredge cuts were deep enough, but the current velocity was too high in the winter. This was eventually solved by changing the operation of a downstream dam to reduce flow through the dredge cuts in the winter.
- Secondary benefits/innovation (i.e. the terrestrial habitat on the islands and dredge material placement sites) is important.

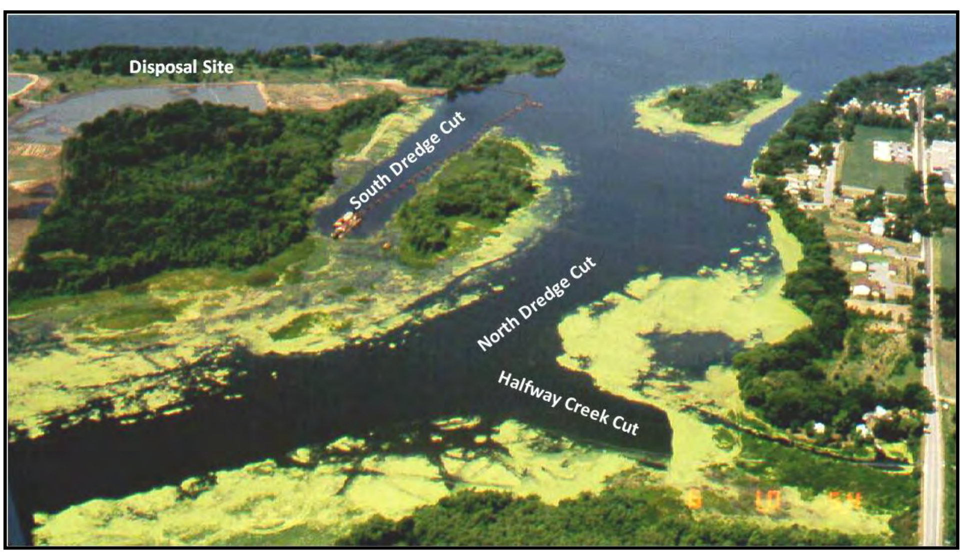


Figure 6-7. Lake Onalaska Dredge Cuts

5. INDIAN SLOUGH HREP
St. Paul District, Mississippi River (RM 760.0 – 758.0))
Feature Constructed 1993

- Dredging in Big Lake (figure 6-8) 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 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.

Figure 6-8. Indian Slough Project Area

6. BUSSEY LAKE HREP
St. Paul District, Mississippi River (RM 616.5-617.5)
Contract Number DACW37-92-0015 and DACW37-95-C-0024
Feature Constructed 1992-1996

- Stage 1 included dredging 12,000 linear feet of channel (photograph 6-8) in the lake to rehabilitate fish habitat. The channels had 75-foot bottom widths with 1 vertical to 6 horizontal side slopes. The majority of the channels were dredged to a depth of 8 feet. In a few locations, channels were dredged to 6 and 7 feet deep to create more bathymetric diversity while minimizing dredging volumes.
- Half the dredged material was placed at the Guttenberg Waterfowl Ponds project to create and additional moist soil unit and to improve operability of the existing ponds. The rest was placed at the Willow Island placement site just downstream of Bussey Lake
- Stage 2 installed a gate on an existing culvert to control flow from Buck Creek into the north end of Bussey Lake. Deepening 29 acres of Bussey Lake expanded available fish habitat, and gated structure reduced sediment transport into the lake.

Lessons Learned

- Verify elevations of the dredge cuts to create different depths and vary habitat
- Add artificial bottom structure to dredge cuts to improve fish habitat
- Consider constructability along with habitat values when designing dredge cuts to maximize efficiency; i.e., habitat gain per unit of cost.
- Dredge production reduced with coarse material.
- Secondary benefits/innovation is important

Photograph 6-8. Bussey Lake Channels

7. POTTER'S MARSH POOL EMP
Rock Island District, Mississippi River (RM 526.0-522.5)
Contract Number: DACW25-93-C-0115
Feature Constructed: 1993-1996

- Included construction of a sediment trap, dredging was done in the upper/lower sloughs and embayment areas creating both shallow and deep water habitat, pothole excavation, and construction of a managed marshland (figure 6-9).

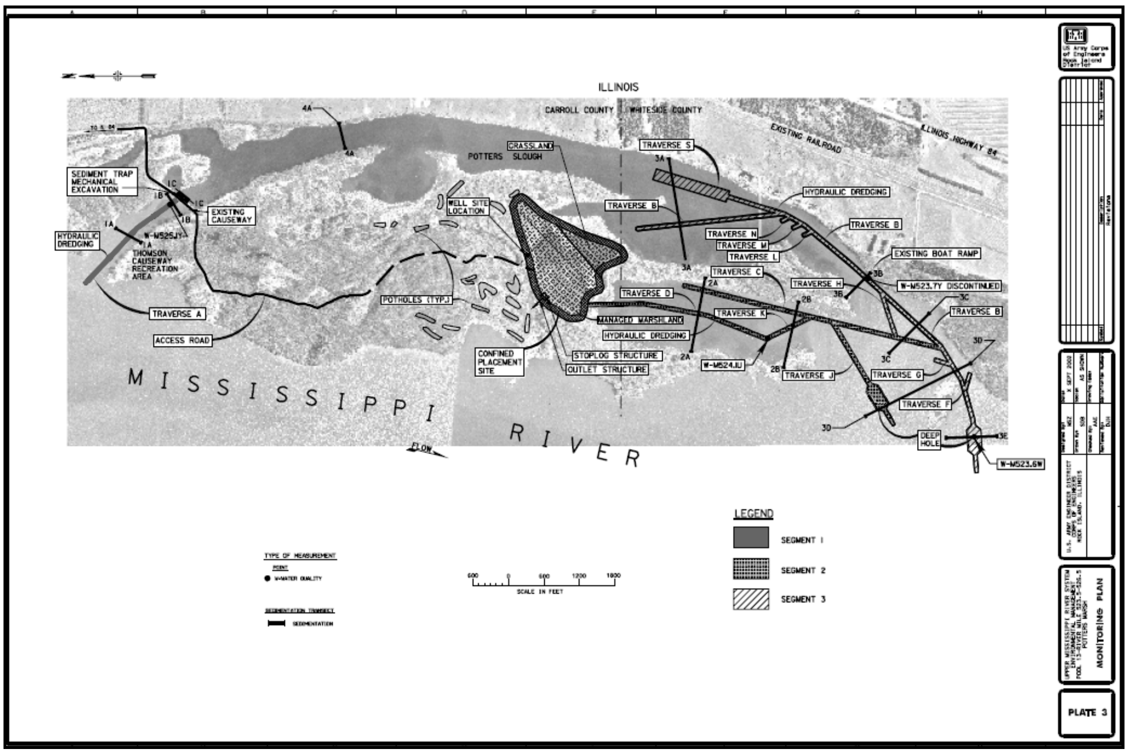


Figure 6-9. Potter's Marsh Site Plan

- Dredged material was placed in a confined disposal site located in an area of secondary growth adjacent to Central Island. The location and shape of the placement site were defined so as to not inundate the lower lying marshland areas downstream and to the east as well as the heavy timber and natural potholes to the north.

- Column settling analyses were performed to determine the required detention time and total for initial dredged material containment. The dredged material needed about 25 hours of settling time and required an initial volume of approximately 1.75 times larger than the in situ sediments. Based on these analyses the interior area of the placement site needed to be 35.5 acres with a perimeter dike 14 feet high.

- The dredged material was placed to an initial depth of 12 feet, settling to a depth of 8 to 10 feet after the first year. At that time, the perimeter dike upper surface was lowered to approximately 2 to 3 feet above the dredged material.

- After settlement of the dredged material, an approximate 32.5-acre marshland was constructed on the confined placement site (photograph 6-9).

Photograph 6-9. Potter's Marsh Managed Marshland Beaver Activity

8. PEORIA LAKE HREP
Rock Island District, Illinois Waterway (RM 181.0-162.0)
Solicitation Number DACW25-93-B-0035
Feature Constructed 1993-1997

- Included construction of a forested wetland management area (photograph 6-10), a barrier island, and restoration of a flowing side channel (figure 6-10).
- The barrier island (photograph 6-11) was constructed using mechanically dredged soft sediments with gentle placement on the adjacent site using multiple passes for island stability. A minimum 7 CY clamshell bucket was included in the dredging scope. This requirement slightly increased the mobilization costs (the contractor was from Louisiana) but it drastically reduced the per unit cost of dredging the material. A clamshell bucket was selected because it can excavate large soil masses without significantly disturbing the internal strength of the soil and it produces the least turbidity compared to dragline or backhoe buckets. This type of dredging was selected due to its cost effectiveness and maximization of soft sediment placed on the island that promotes re-establishment of vegetation for habitat enhancement.

Performance: Overall the project is performing reasonably well. The barrier island has been stable and is providing a wind break, although the overburden island has deteriorated. The forested wetland management area has provided usable water fowl habitat and the East River Channel is still open.

Photograph 6-10. Peoria Lake Forested Wetland Management Area

Photograph 6-11. Peoria Lake 2010 Google Earth Aerial Photo

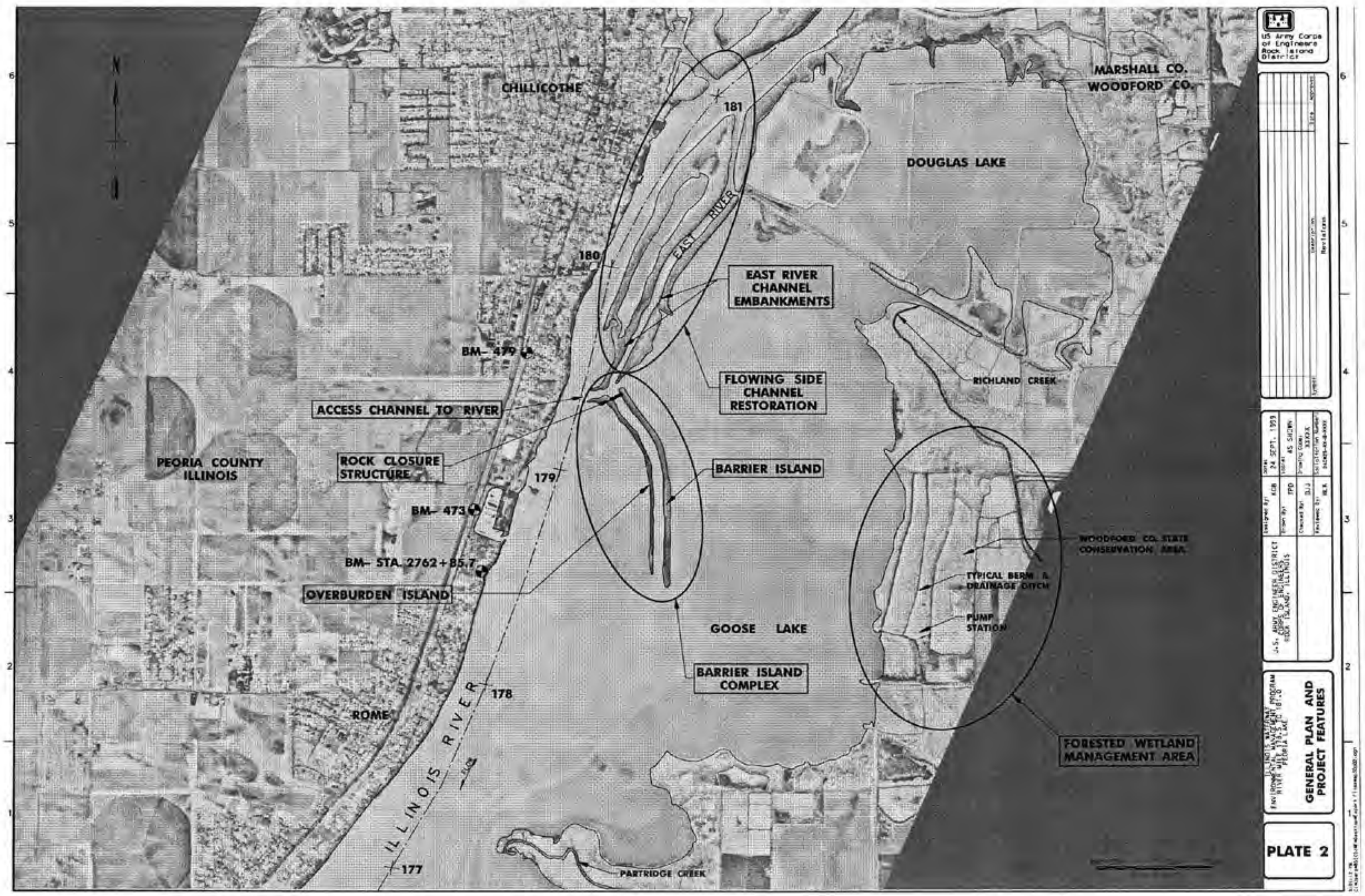


Figure 6-10. Peoria Lake Enhancement Site Plan

9. LONG ISLAND (GARDNER) DIVISION HREP
Rock Island District, Mississippi River (RM 340.2-332.5)
Contract Number DACW25-01-C-0008
Feature Constructed 2001-2002

- Included side channel restoration (photograph 6-12) and protection within O'Dell Chute including a closure structure along with shoreline protection and reforestation (figures 6-11 and 6-12).

- The material dredged from O'Dell Chute and the closure structure access channel was placed on a 184 acre agricultural field on the eastern end of Long Island. It was determined that up to 8 inches of the sandy dredged material could be incorporated into the existing soil and still support the reforestation plan. To ensure that this depth was not exceeded, a 60 to 80 acre site was used. A berm was constructed on three sides of the placement site to ensure the dredged material settled out before draining to Long Island Lake. The berm is 2 feet in height with 2H:1V side slopes. It was assumed that the fine to medium sand making up the dredged material would settle quickly, therefore a column settling analysis was not performed.

Performance. A Performance Evaluation for this project will be finalized in FY13.

Photograph 6-12. Long Island Small Hydraulic Dredge

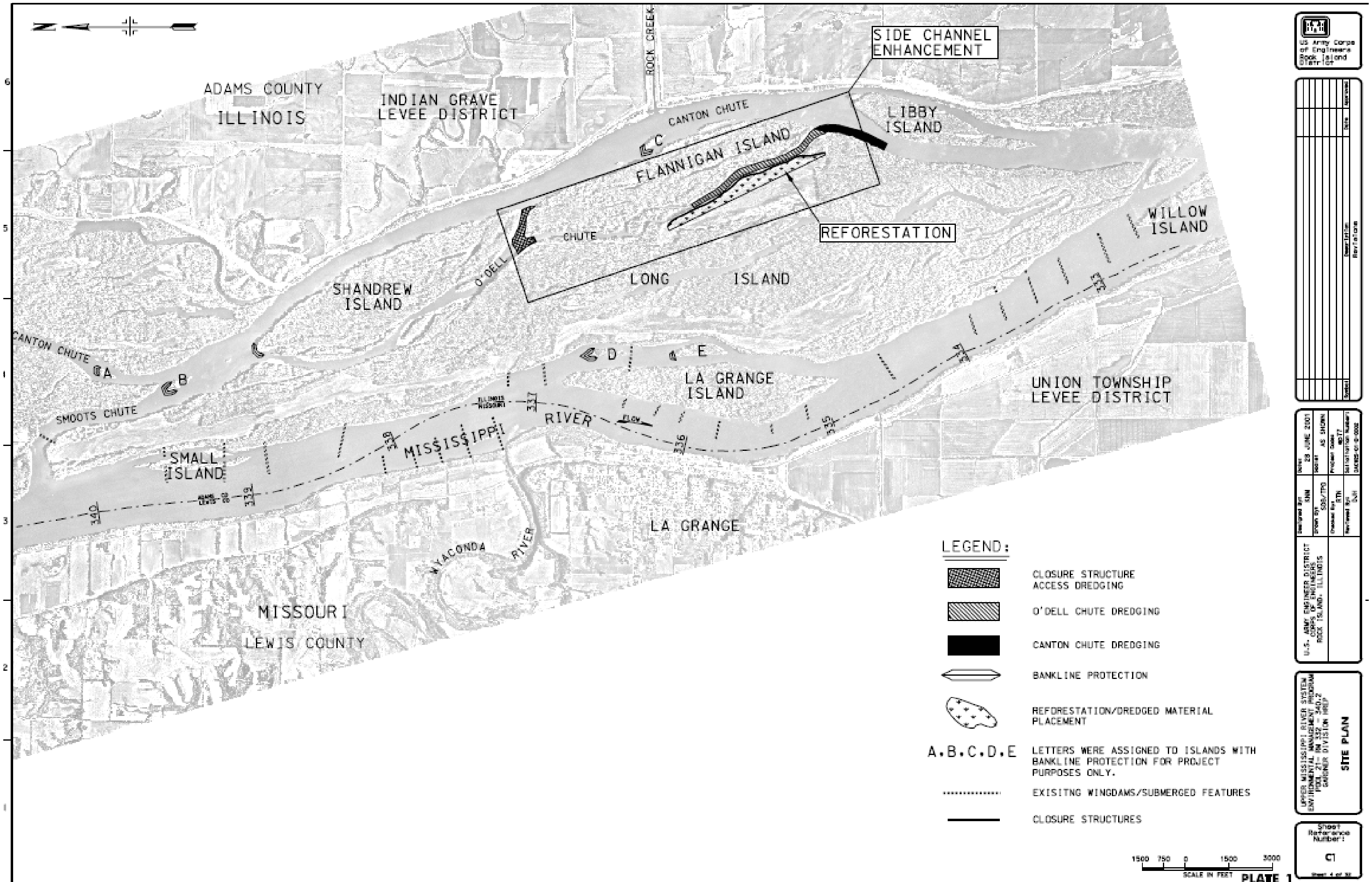


Figure 6-11. Long Island Site Plan

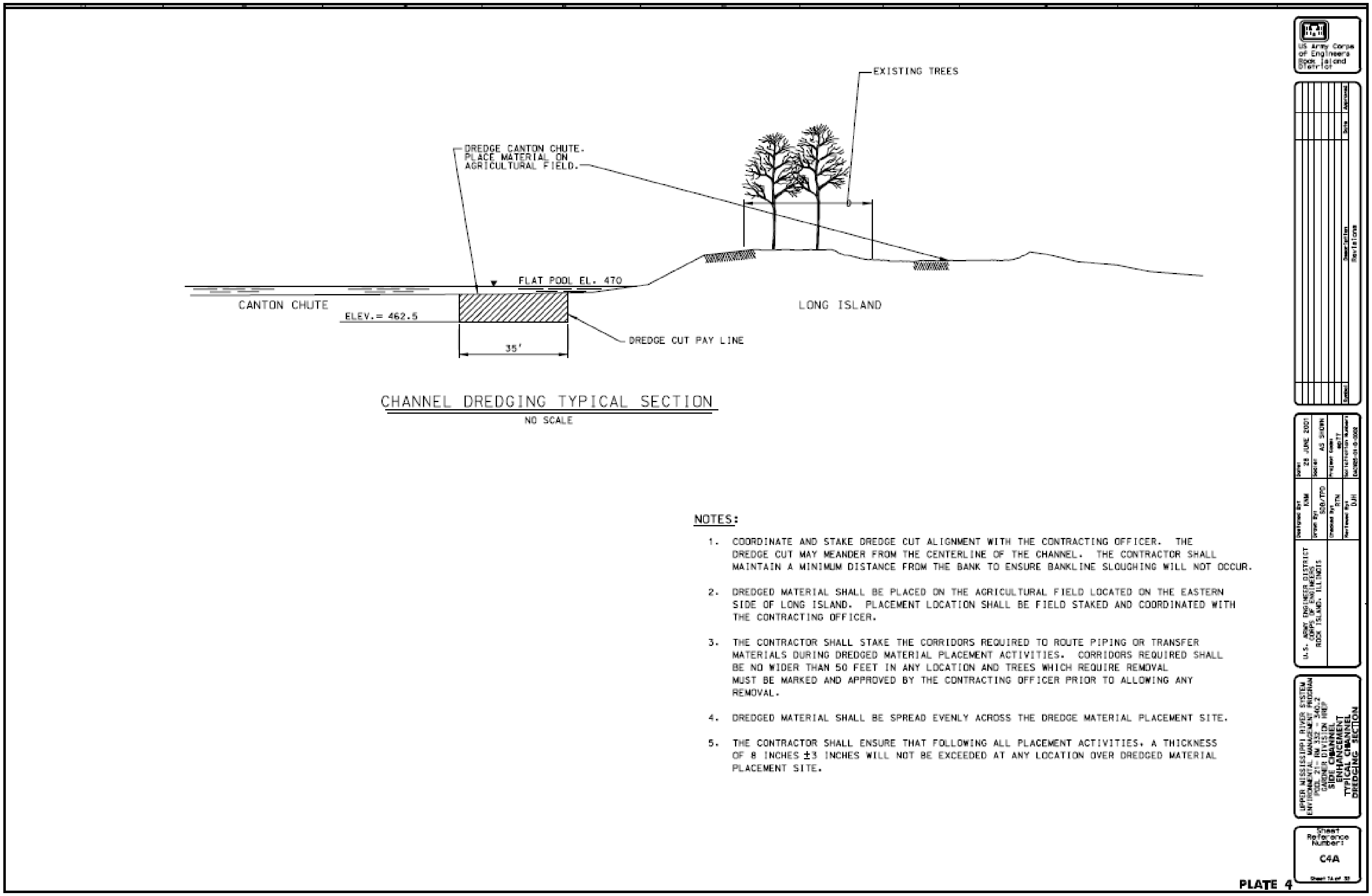
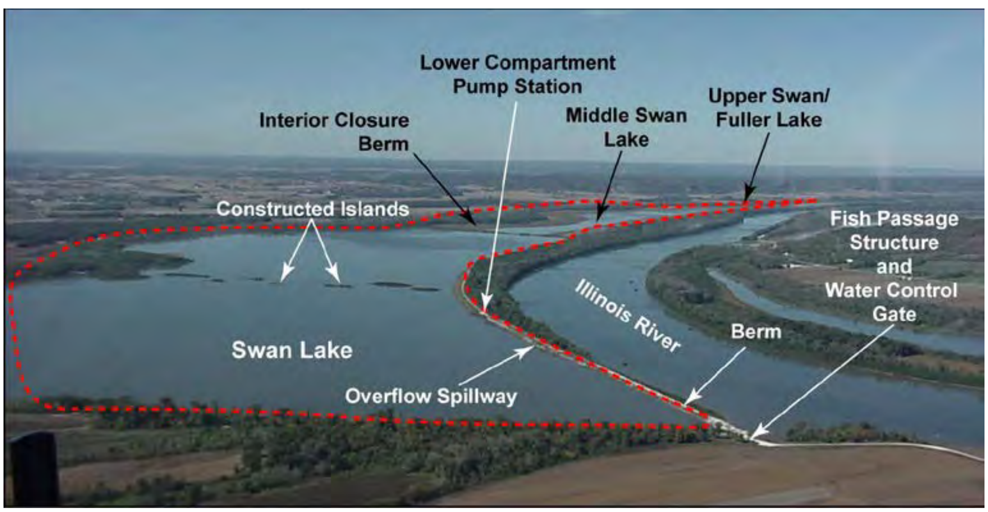


Figure 6-12. Long Island Channel Dredging Typical Section

10. SWAN LAKE HREP
St. Louis District, Illinois River (RM 13.3-15.0)
Feature Constructed 2001

Swan Lake (photograph 6-13) is a bottomland lake approximately 2,900 acres in size with average depth between 3 and 3.5 feet. This is the largest backwater complex in Pool 26 of the Mississippi River and one of the largest on the Illinois River. The design of the Swan Lake HREP was to provide the physical conditions necessary for creating a wide spectrum of strategies for waterfowl and fisheries management. The Swan Lake HREP consisted of riverside levee, dredging, water control/fish passage structures, pumps, an interior closure structure, islands, hillside sediment control basins, and service access. The riverside levee was necessary to reduce siltation that occurs from frequent floods from the Illinois River. Dredging provided deep water fish habitat and was accomplished in conjunction with the construction of the riverside levee. Fish passage water control structures were constructed to separate Swan Lake from the Illinois River while still providing fish passage. The hillside sediment control, which was in partnership with the NRCS, included 25 water and sediment basins in the upland watersheds to reduce sediment transported by tributaries flowing in the lake. These sediment traps were constructed by farmers on a volunteer basis after they were approached by NRCS. Islands were constructed to serve as barriers to reduce turbidity from wind generated wave action.



Photograph 6-13. Swan Lake Aerial Layout

Sedimentation continues to be one of the largest obstacles to meeting the goals of the Swan Lake HREP. The annual sediment inputs from the watershed as well as resuspension of the flocculent material by wind generated wave activity continue to contribute to lose substrates and increased turbidity. The Lower Swan Lake area is now viewed as a sacrificial sediment trap, which in future HREPS sediment traps should be designed into the project. Instead of managing this area for backwater fish habitat, this area is much more suited for management as a moist soil unit. On years with successful draw downs, abundant emergent vegetation grows, providing significant forage for waterfowl as well as for the aquatic invertebrates that colonize these areas in the spring.

Performance. A performance evaluation report was completed in 2007 to evaluate the success of the HREP. The report stated the water quality, sediment depth, and emergent vegetation improved in Middle Swan Lake, while no improvement was seen in Lower Swan Lake. It was also indicated that no submerged or rooted floating vegetation occurred in any section of the lake, likely due to an absence of a seed bank and tubers. Most notably, the report indicated fish assemblages did not improve in either section of Swan Lake. The lack of firm substrate and vegetation negatively affected the quantity of fish species present and, for the fish present, they were small and likely juvenile. In contrast, the presence of diving and dabbling ducks increased.

11. POOL 11 ISLANDS HREP
Stage I and Stage II
Rock Island District, Mississippi River (RM 165.5-166.0)
Contract W912EK-02-C-0024 and W912EK-04-C-0007
Feature Constructed 2002-2005

- **Stage I - Sunfish Lake (figure 6-13).** Downstream of the deflection embankment, a series of deep-water channels totaling 13.1 ha (32.37acres) were dredged. A 2-cell containment area was constructed as part of the deflection embankment to hold the hydraulically dredged material. Both the hydraulically and mechanically dredged channels were excavated to a bottom elevation of 181.31 m (594.85 ft), a bottom width of 10 m (32.81 ft), and side slopes of approximately 3H:1V(figures 6-14 and 6-15) . The hydraulically dredged channels were dredged by an 8 inch hydraulic pipeline dredge. The mechanical dredging was done by a 275 ton crane with 3 and 4 yard buckets. Additionally, the side slopes of the hydraulically dredged channels were constructed in a stepped fashion. Dredging depths were based on historic sedimentation rates. There are two channel alignments (A & B) that follow the deflection embankment. The additional channels (D through M) connect to the first channel alignments and extend east and south towards the shoreline.
- **Stage II - Mud Lake (figure 6-13).** The borrow for the Mud Lake embankment was mechanically dredged from the river bottom, landward and adjacent to the embankment alignment. The resulting deep-water channel was excavated to a bottom elevation of 181.45 m (595.31 ft), a minimum bottom width of 10 m (32.81 ft), side slopes of approximately 3H:1V, and a total 11.2 ha (27.62 acres) of bottom area (figures 6-16 and 6-17). Several high spots were created with riprap in the dredged channel to retain the warmer bottom water during overwintering periods.

In the case of both islands, the dredged material was used to create the off shore revetments which would create the perimeter of the EMP site. The revetments consisted of earthen embankments covered protected by rip rap on the riverward and end sections.

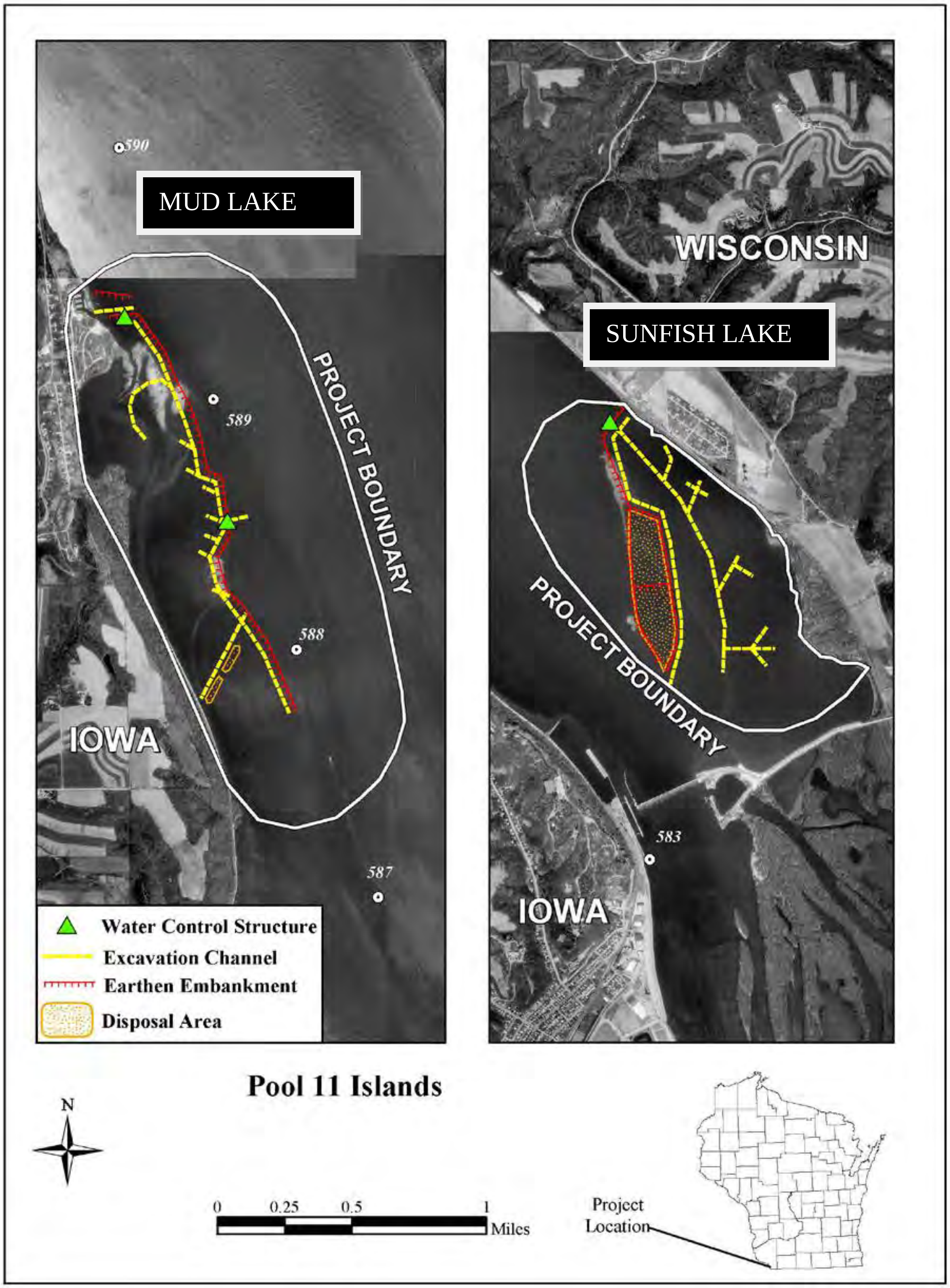


Figure 6-13. Pool 11 Islands

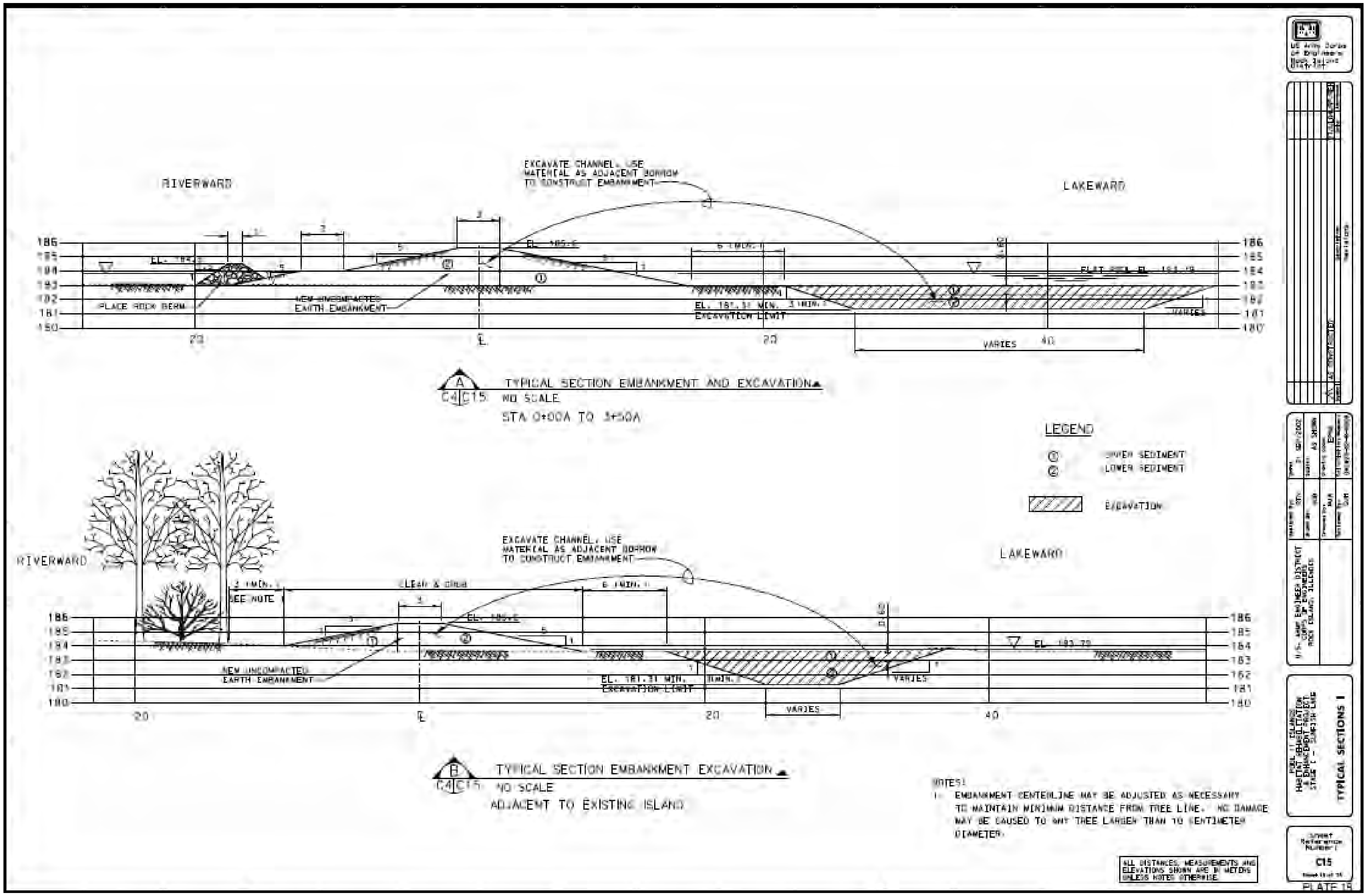


Figure 6-14. Sunfish Lake Typical Section I

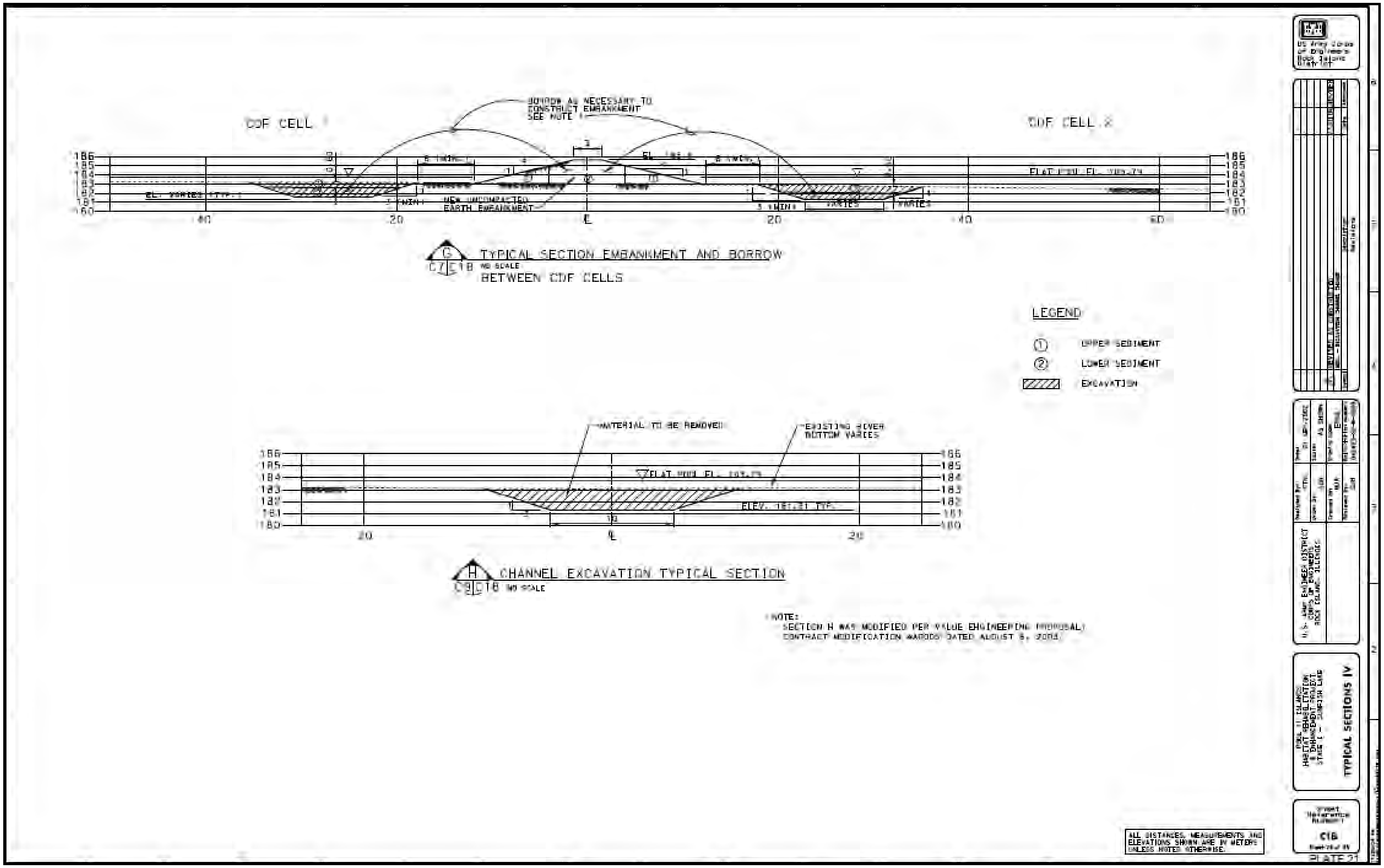


Figure 6-15. Sunfish Lake Typical Section IV

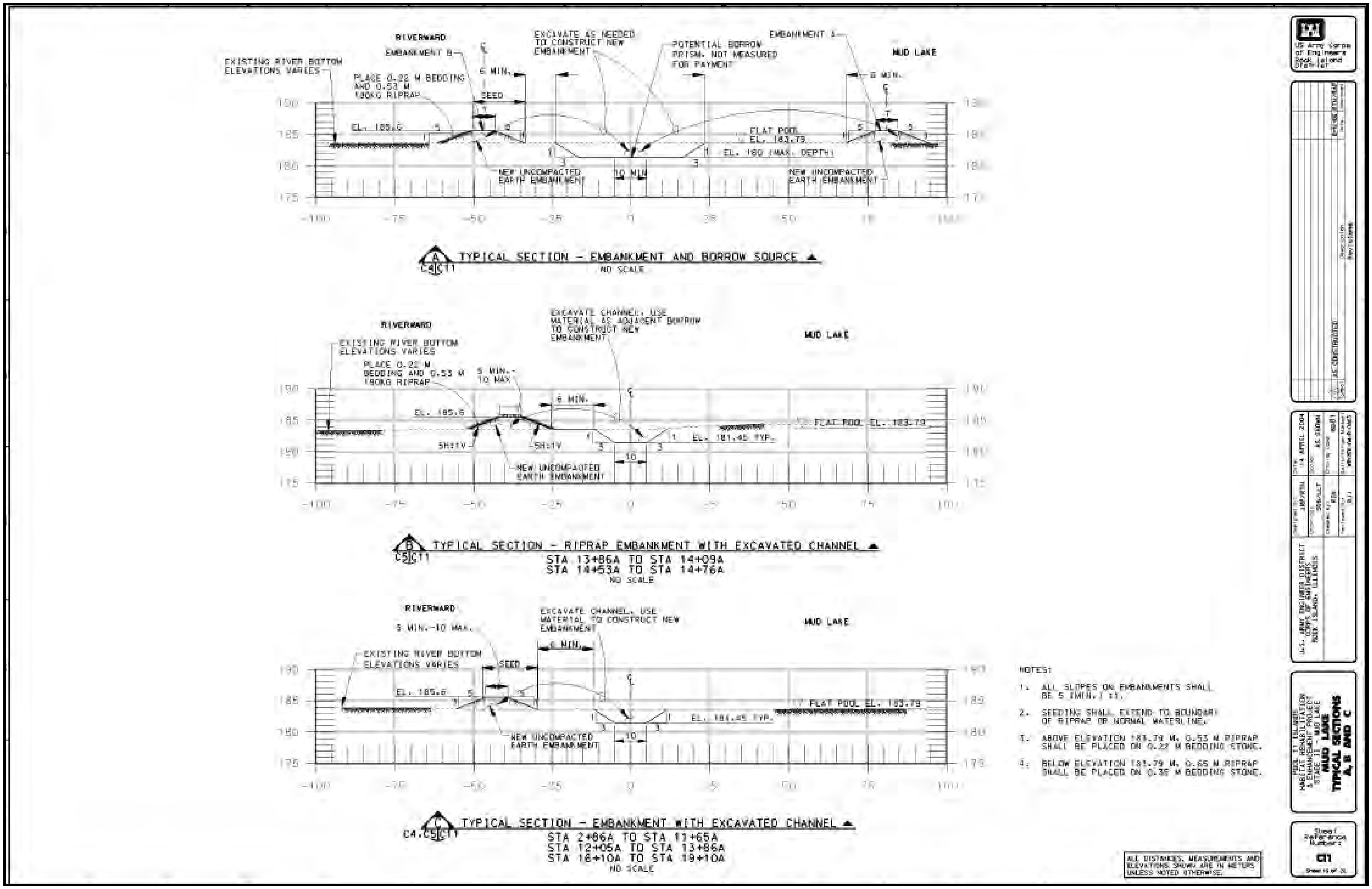


Figure 6-16. Mud Lake Typical Sections A, B and C

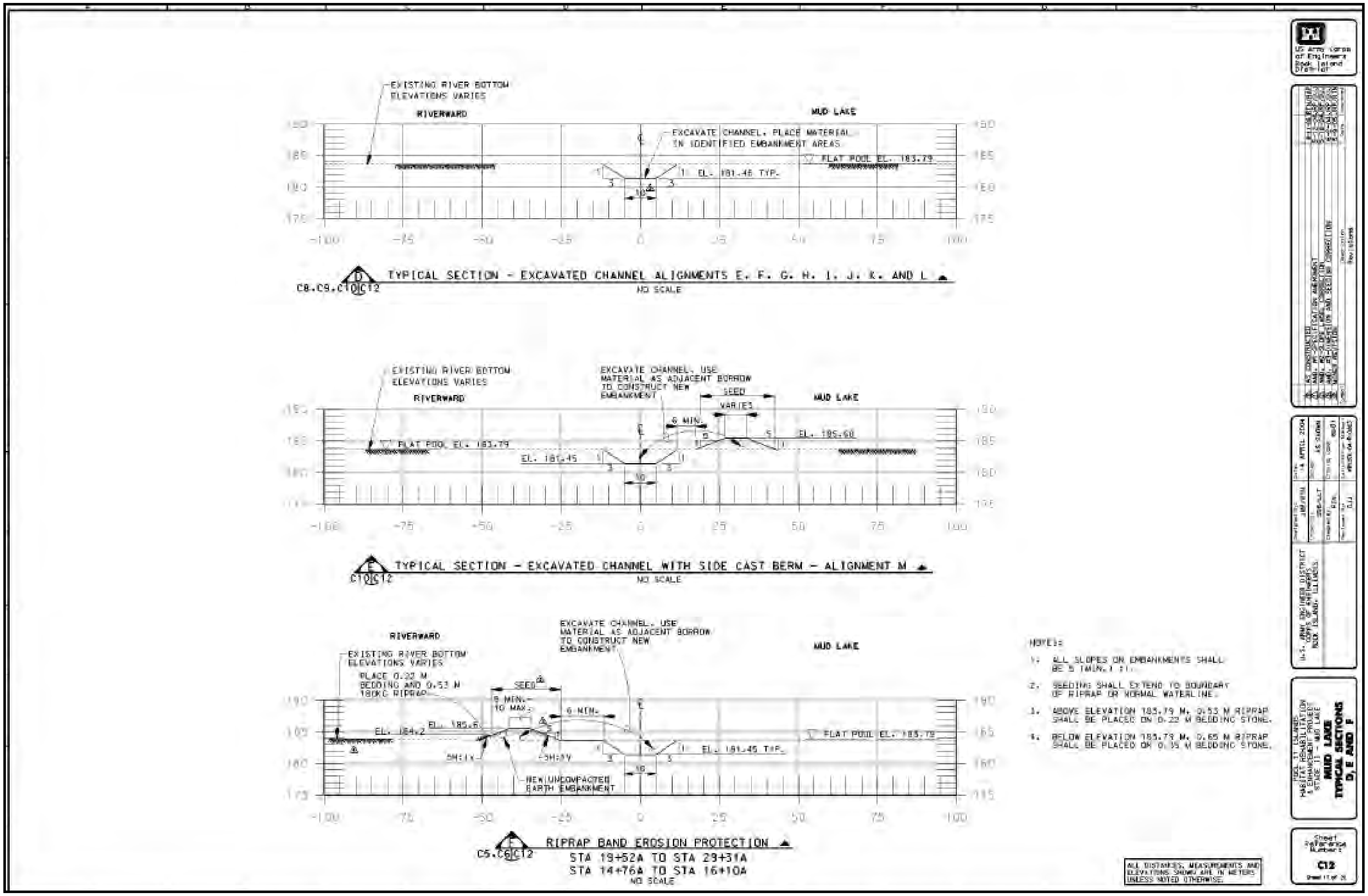


Figure 6-17. Mud Lake Typical Sections D, E and F

To control sediment deposition in the newly dredged channels, three sedimentation traps (figure 6-18) were constructed to retain the majority of the expected sediment passing through three notched rock weirs. Each island contained a sedimentation trap on the upstream end of the island. In the design of each, the sediment trap was sized to allow for a 50-year lifespan based on historical accumulations. The traps were mechanically dredged to the approximate dimensions of 5 feet wide, 10 feet long, and 1.5 feet below flat pool. The upstream ends of the traps were located 25 to 40 feet downstream of the weirs, and 1V:3H transition slopes were used. A survey is scheduled to be completed every 5 years to monitor performance.

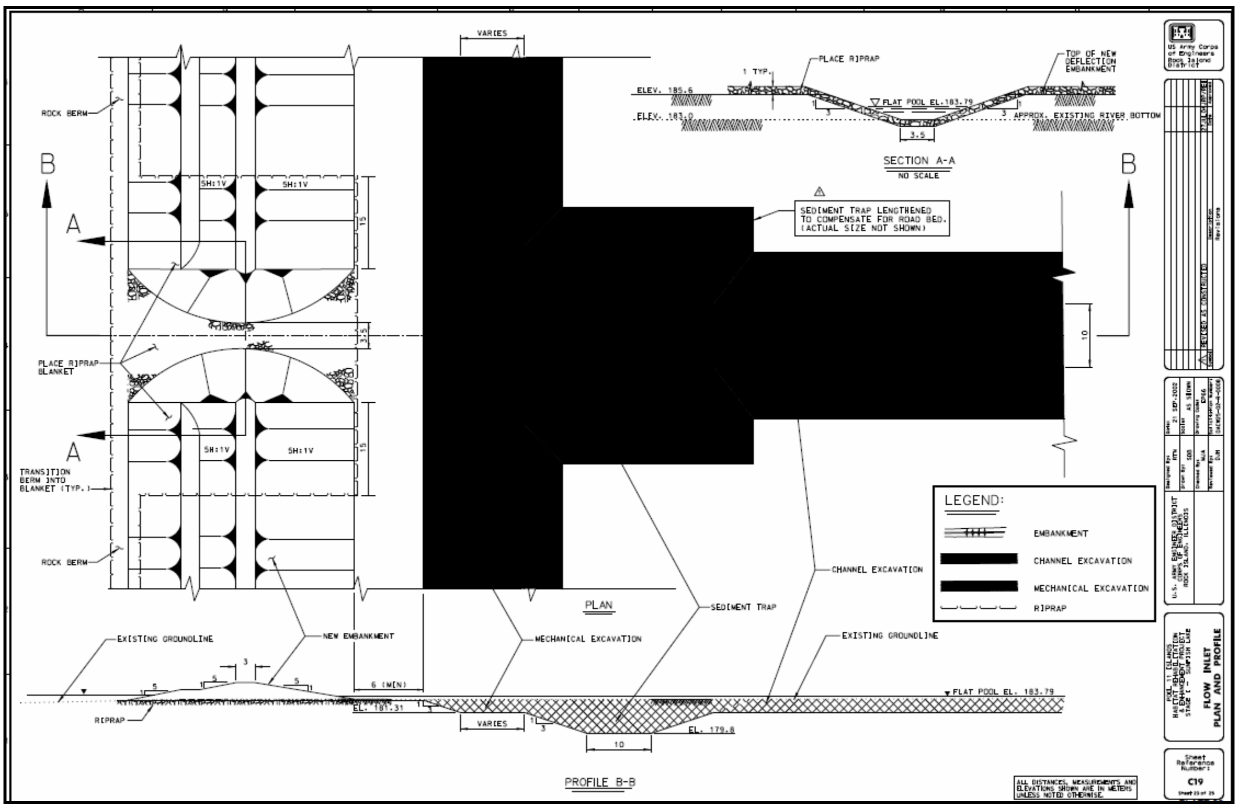


Figure 6-18. Sediment Trap Plan and Profile

Performance. A Performance Evaluation report was completed in 2002 after 2 years of performance. The results of the report were inconclusive as some features of the project had not yet been completed or were not operating correctly. The report did, however, note conditions for aquatic plant growth were favorable. A subsequent performance evaluation report has not been completed.

12. LAKE ODESSA HREP
Stage IIB Channel Excavation
Rock Island District, Mississippi River (about RM 440-435)
Contract W912EK-10-C-0018
Feature Constructed 2009-2011

This feature involved dredging an existing channel (Blackhawk Yankee Chute) to create overwintering and over-summering access between the two channels. The location is within a managed water unit, and the minimum managed pool elevation is 532.5. The channel was to be excavated to 526.5. The dredge bottom width was set at 30 feet, which was a reasonable minimum distance to get a barge floated excavator into this area (figure 6-19 and 6-20 and photographs 6-14 to 6-16). Anything narrower would have required special equipment. Anything wider would have gone outside of the existing channel. The material being dredged was such that very steep side slopes could be constructed. A minimum distance between the dredge cut and the placement site was set to ensure that dredged material would not easily re-enter the dredge cut. The placement site height was established to ensure a minimum impact on wetlands (it was set at an elevation such that it could still be considered a wetland), and at a width that was reasonable to reach with the mechanical dredge.

Originally, the material was to be hydraulically dredged and pumped to a moist soil management unit located on the southern edge of the project. The feature was awarded with other dredging as part of the Stage IIA project. When the contractor entered this area, it became apparent that the material to be dredged could not be efficiently dredged hydraulically, which is how the contract had been bid. (The rest of the material being dredged could be hydraulically dredged.) After many attempts to modify the existing contract, based on the contractors characteristics and abilities, and the "changed site condition" this feature was removed from Stage II. A new contract, Stage IIB was awarded which allowed for mechanical dredging. Additional dredging was also completed as part of this contract.

Lessons Learned

- Have many borings, especially in backwater areas. The materials changed over a very short period of time, creating a need to change the type of construction equipment required to complete the job.
- Have adequate environmental clearance before proceeding with a project. This project required additional coordination to sidecast.
- Understand the site conditions and go into the field with team members and sponsors to discuss. A drawing indicating where tree clearing may be required is often not adequate, especially in high diversity areas.
- Field stake dredge cuts AND placement sites. A centerline situated on a drawing or using survey data does not always match the field conditions.

Performance. There has not been a Performance Evaluation report for this project as of 2012.

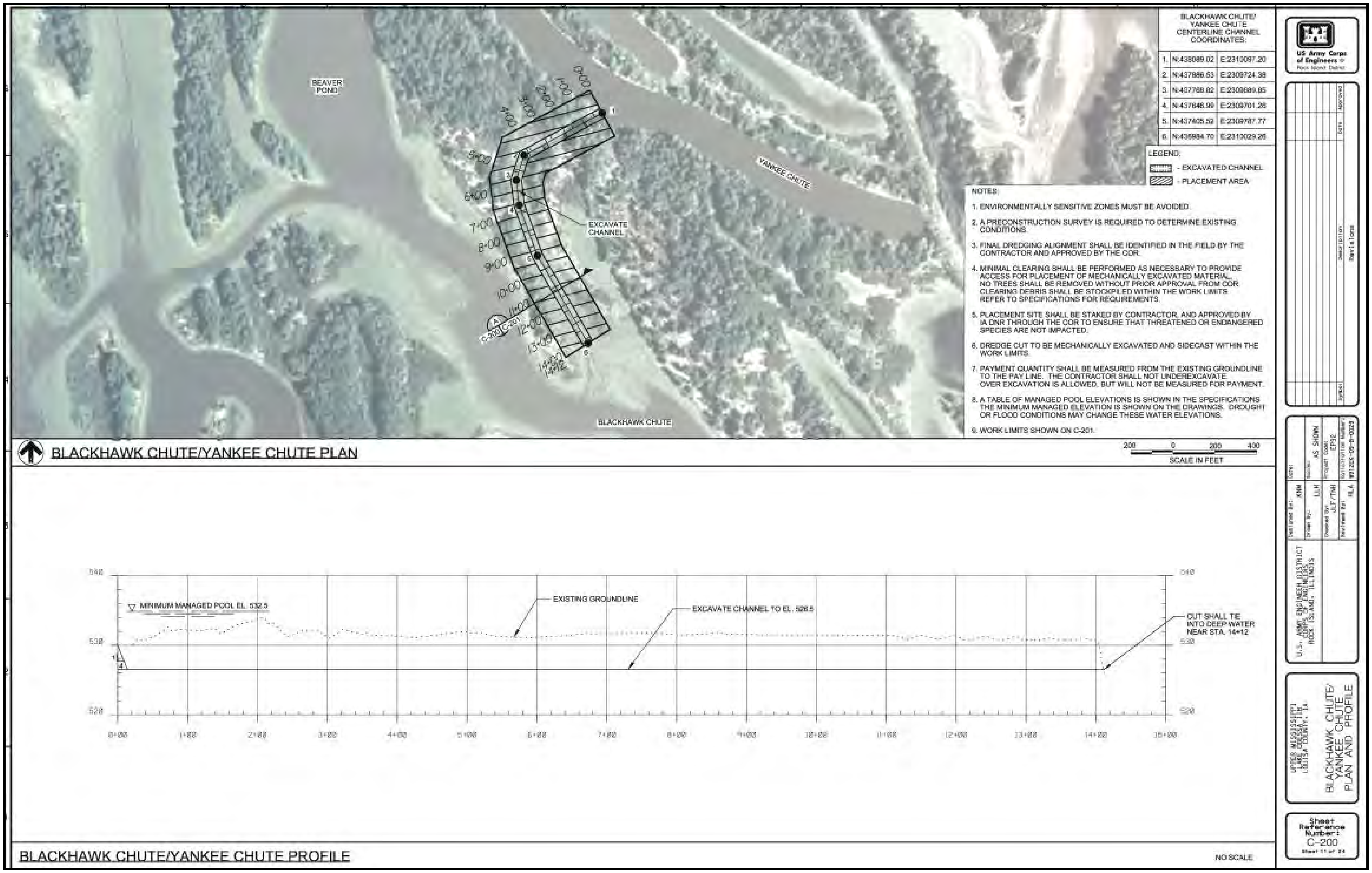


Figure 6-19. Blackhawk Chute/Yankee Chute Plan

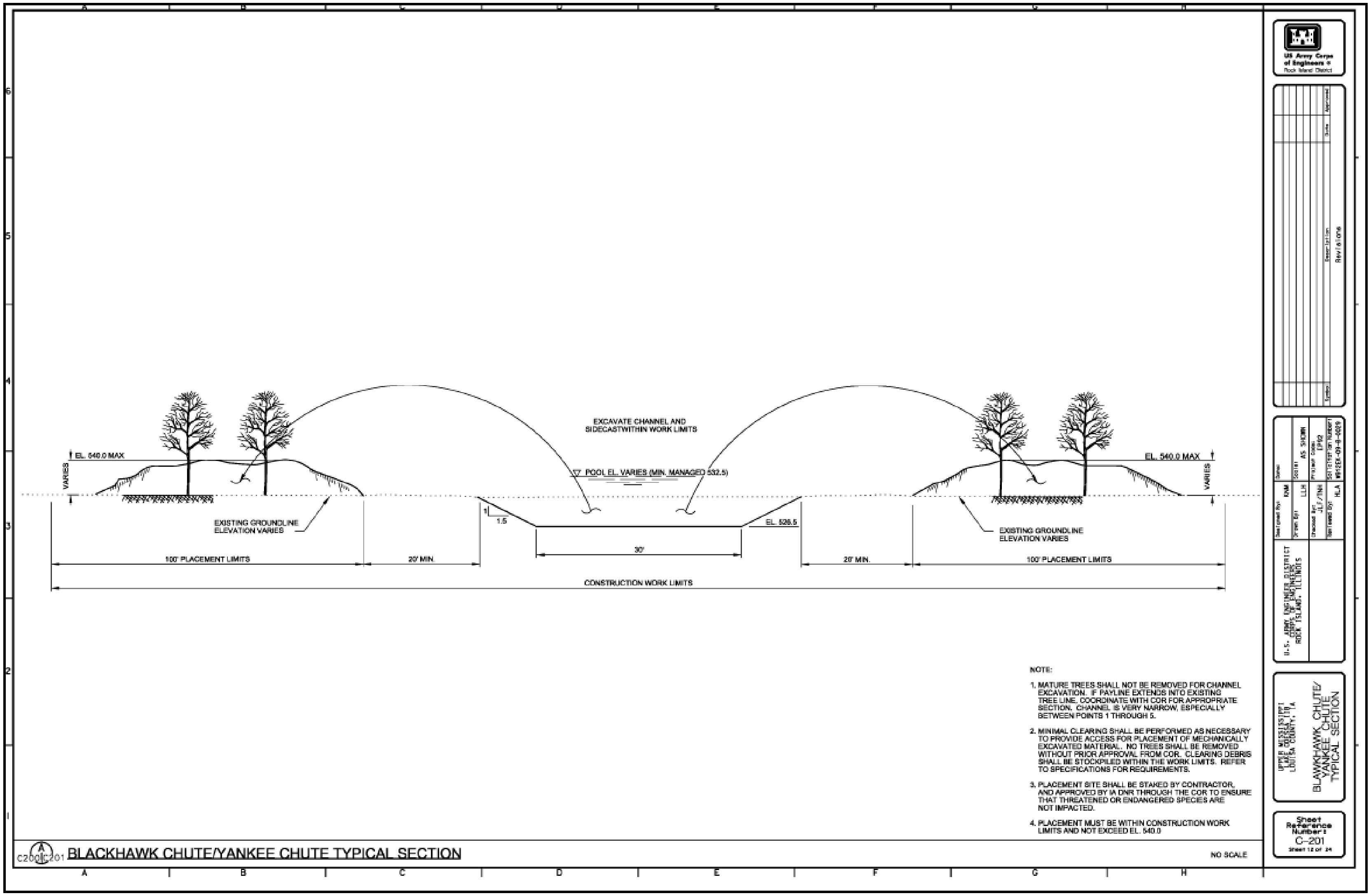


Figure 6-20. Blackhawk/Yankee Chute typical Section

Photograph 6-14. Blackhawk/Yankee Chute Prior To Dredging

Photograph 6-15. Excavator Used To Dredge Back Channels

Photograph 6-16. Construction Considerations in a Backwater Area

13. PEORIA RIVERFRONT DEVELOPMENT UPPER PEORIA ISLAND SECTION 519 Stage I and Stage II
Rock Island District, Illinois Waterway (RM 165.5-166.0)
Contract W912EK-09-C-0052 and W912EK-10-D-0069
Feature Constructed 2009-2011

- Included the construction of an island in Peoria Lake (figure 6-21 and photograph 6-17) using geotextile containers filled with mechanically dredged material. The completed project will allow for improved habitat for fish and waterfowl in the dredged areas, a new habitat created from the dredged material placement, a reduction in the amount of sediment entering Peoria Lake from the Illinois Waterway, and recreational benefits.

- In the first project stage, a high solids dredging methodology was used to fill a three ring wide perimeter of geotextile container in 1 to 5 feet of water. During the second stage, an additional row of geotextile containers were placed on top of the existing geotextile containers and the interior of the island was filled using the same dredging technique as well as double handling with two clamshells (figure 6-22 and photograph 6-18). An approximate 450,000 cubic yards of material were dredged over 55 acres, creating a 21 acre island. The island was constructed at a price of $7 million. The process consisted of mechanically dredging the area and placing dredged materials in a concrete pump to fill the geotextile containers.

Lessons Learned

- Long bags cannot be used on corners.
- Geotextile containers need to be firmly anchored because they will roll when filling.
- Geotextile containers will sink when placed on unconsolidated materials.
- Mark geotextile containers during high flows. Boaters will hit them if they are not marked.
- Maintain geotextile containers height for longer than 48 hours or they will settle too much.

Performance. There has not been a Performance Evaluation report for this project as of 2012.

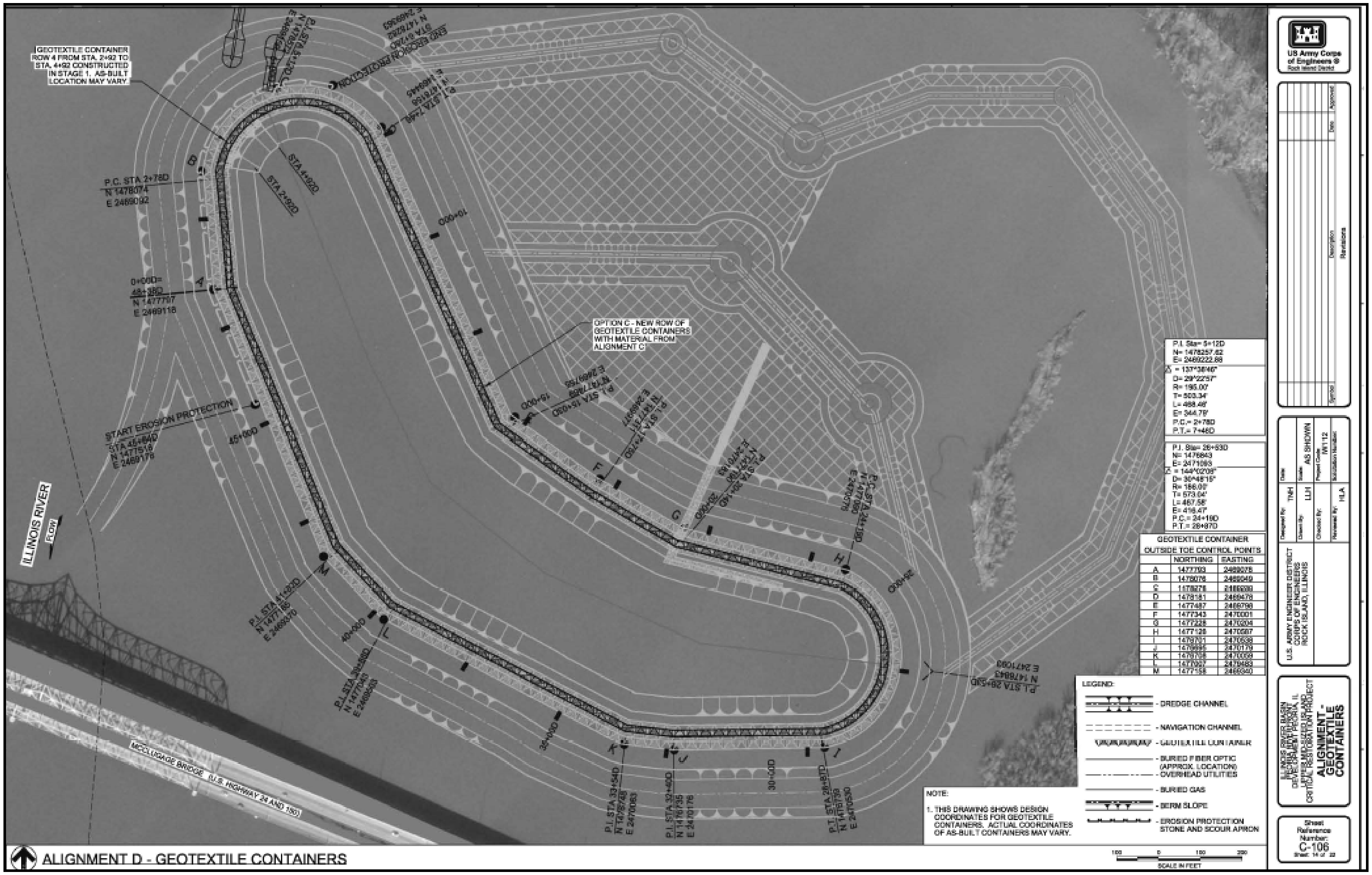


Figure 6-21. Peoria Riverfront Geotextile Containers and Dredging Alignment

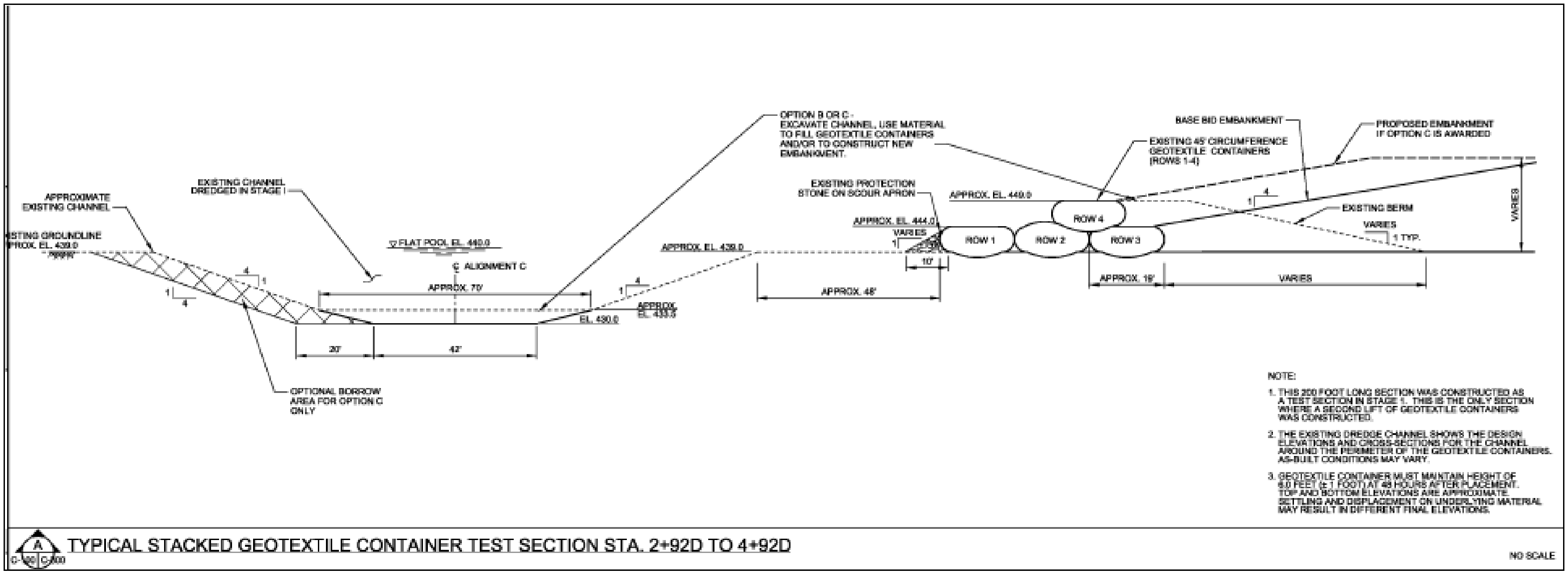


Figure 6-22. Peoria Riverfront Upper Island Section View Stage II

Photograph 6-17. Peoria Riverfront Island Stage 1

Photograph 6-18. Peoria Riverfront Island Stage II

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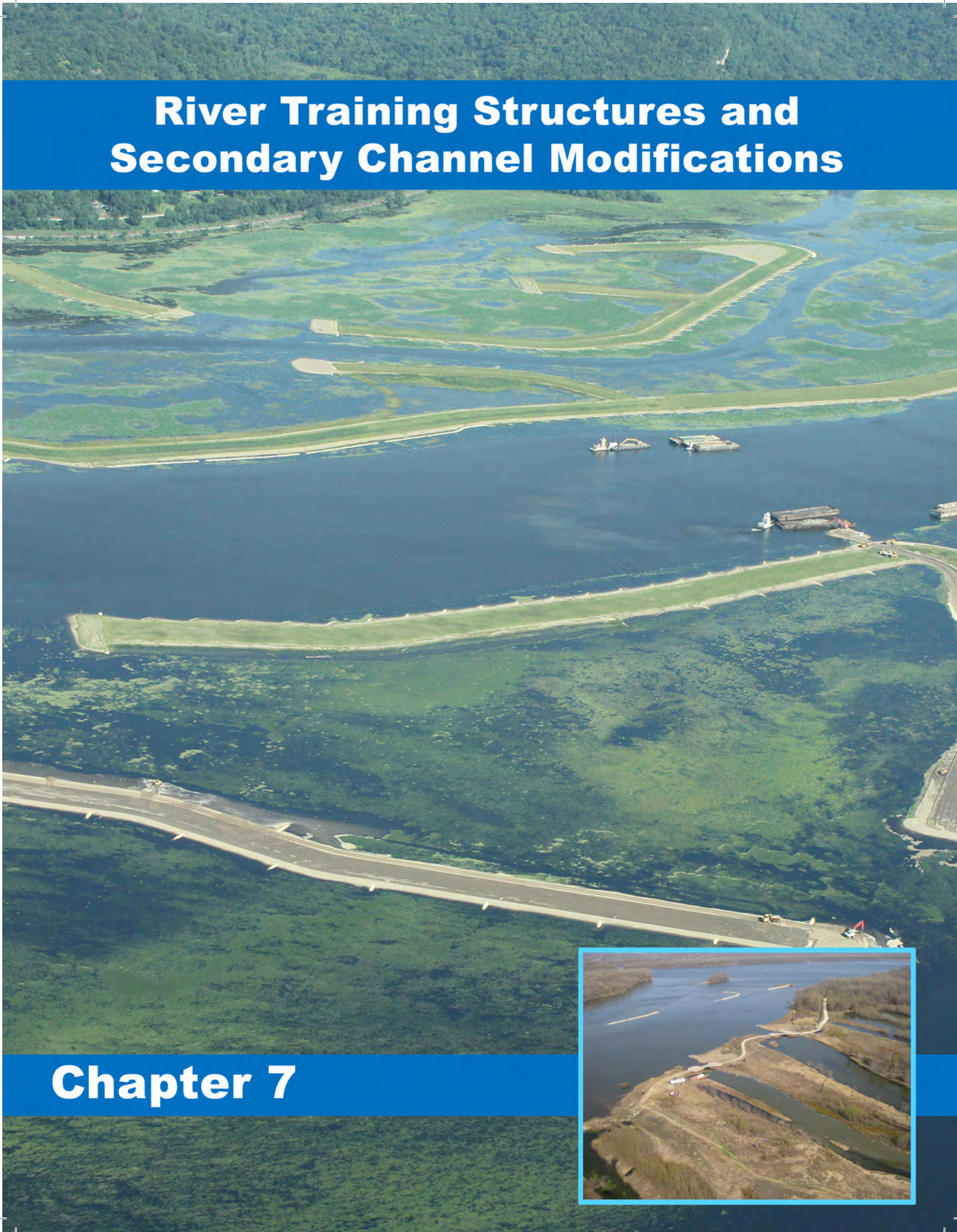
River Training Structures and Secondary Channel Modifications



Chapter 7

UPPER MISSISSIPPI RIVER RESTORATION ENVIRONMENTAL MANAGEMENT PROGRAM ENVIRONMENTAL DESIGN HANDBOOK

CHAPTER 7

RIVER TRAINING STRUCTURES AND SECONDARY CHANNEL MODIFICATIONS

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CHAPTER 7

RIVER TRAINING STRUCTURES AND SECONDARY CHANNEL MODIFICATIONS

PHOTOGRAPHS

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CHAPTER 7

RIVER TRAINING STRUCTURES AND SECONDARY CHANNEL MODIFICATIONS

The US Army Corps of Engineers (Corps) continues to use river training structures to create and maintain a safe and dependable navigation channel for the Mississippi Inland Waterway System. In the past, the navigation channel was typically developed by constricting the channel and closing off side channels. As we become more environmentally conscious, we continue to develop intuitive river training structure designs to maximize benefits for both navigation and river restoration.

A. PRE-INUNDATION CONDITIONS

Human-induced physical modifications of the Upper Mississippi River System (UMRS) channel began as early as 1832 with removal of snags to facilitate steamboat travel (Burke and Robins, 1979). In 1878, Congress authorized a program to provide a navigation channel 4 ½ foot deep in the Upper Mississippi River. This authorization included channel deepening and construction of river training structures, specifically, closing dams, wing dams and rock revetments. These structures continue to concentrate the river flow and force it to scour out a deeper navigation channel. They also reduce bankline erosion on outside bends of the river.

As subsequent Congressional authorizations raised the depth of the UMRS navigation channel, the Corps' use of river training structures, along with dredging, continues to be the most economic tools for maintaining the current 9-foot operating depth.

B. RESOURCE PROBLEMS

In all the regulated sections of the UMRS, the construction and maintenance of locks and dams have altered physical habitat for fish, invertebrates, and plants by changing stream flow from free-flowing to impounded, and altering the natural hydrology and the physical structure of the channel. As a result, the river has changed from a meandering, flowing system, which periodically overran its banks and floodplain, to a series of impoundments connected by dredged channels where the Corps controls the stream flow and water levels. The impoundments changed the physical structure of the river, the diversity of aquatic habitats, and water quality.

Impoundments reduce the velocity and warm the water in the pools. Reduced velocity causes sediment to settle, changing the composition of the substrate on the bottom of impoundments to fine-grained material (sand and silt). Nutrients and contaminants associated with sediment particles are concentrated in the bottom sediments of the pools (Stark, et al., 2000).

Today's URMS pools, regulated by the series of locks and dams, have shown significant changes exemplified by the loss of islands in the lower pool, and filling of backwaters with sediment.

The following are some river conditions challenging engineers and biologists to develop sound solutions to today's navigation and river restoration missions.

1. **Meandering River Channel.** As a typical alluvial channel the Mississippi River likes to meanders back and forth along its floodplain, constantly realigning itself. This natural meandering process is the river's attempt to restore balance in the system by eroding its banks, and reducing the overall energy in the system. As the Mississippi River travels south, sinuosity increases linearly, as velocities increase. The bends can create a turning challenge to 1200 foot barges trying to navigate in strong currents, especially when passing a barge going the opposite direction. The Corps' channel maintenance is also tested at these bend areas due to shoaling in the slack area, or inside of the bend, and eroding or shifting channel on the outside of the bend.

The outside of a river bend is the location of the majority of the channels energy. Depending on the bank material, the river likes to erode the bankline and eventually cut new channels in areas where it makes sharp twists and turns. This incorporates additional sediment to the system which must be deposited downstream.

In places where the current hits a protruding river bank, it begins to wear down the exposed bank, eventually forming a side channel and later a main channel.

2. **Eroding Banklines.** Banklines on both sides of the river are exposed to erosion. The bankline along the fast moving side of the river is exposed to the river's relentless current, scouring above and below the water line. The river bank running along the slow side of the river can also be exposed to erosion. Wind, rain, man, and the river itself all contribute to the loss of bankline stability.

3. **Tributary Effects.** Tributaries introduce a large portion of sediment into the system. Land use change, whether it has been urbanization or agricultural fields, has played a major role in the stabilization of tributary banks. Many of the riparian corridors have been destroyed and channel straightening has occurred. Unvegetated banks contribute to excessive erosion and channel straightening leads to headcutting, which induces massive bank failures due to downcutting. All of the added sediment in the tributaries is eventually passed to main stem, in this case the Mississippi River. This has a major impact on the Mississippi Rivers ability to transport sediment and maintain backwater sections of the river.

4. **Sedimentation/Navigation Concerns.** Each year the Mississippi carries approximately 130 million tons of sediment to the Gulf of Mexico. That which does not reach the Gulf adds approximately 300 yards to the State of Louisiana each year. The rest is deposited in the river channel. How much and where depends on the velocity of the river and the size and depth and width of the channel.

Historically, dikes and other river training structures were strictly used to constrict flow, increasing the channels ability to transport sediment. This was done to maintain a safe and dependable navigation channel. Today, river training structures continue to maintain the navigation channel but new designs attempt to preserve and enhance the environmental component of the channel.

Streambank erosion throughout the basin is another important source of sediment filling backwaters. Backwater restoration is required throughout the UMRS.

5. Sedimentation/Biological Concerns. Sedimentation is a naturally occurring phenomenon. Traditionally, it is managed through the use of river training structures and dredging. Disposing of the dredge material in an appropriate manner can also negatively impact the environment.

To a biologist, sedimentation is the process of turning an aquatic environment into a terrestrial habitat. While biologists look favorably on both environments, eliminating one in favor of another is unhealthy. Healthy ecosystems need a variety of diverse environments.

Sediment diminishes the river by destroying aquatic life. Biological diversity is best achieved with a variety of river habitats including slow water and wetted edge, often found along banklines. The effects of sediment deposition, and sediment resuspension that blocks light required by aquatic plants resulting in loss of aquatic plant communities, shoreline erosion, and secondary channel formation has resulted in degraded habitat in the navigation pools.

6. Homogeneous Environments. One long, deep river creates a homogeneous unhealthy environment. Ecosystems are built on food webs. Protozoa are consumed by insects, which are consumed by small fish. They small fish are consumed by large fish that are consumed by man and other predators. Different species require different habitats to breed, raise their young and survive. The healthiest ecosystem offer diverse habitats accommodating the greatest number of species.

7. Narrowing of Channel Widths in River Bends. Since the late 1800s, when revetment and stabilization work began, the river has found ways to challenge man's ability to harness its tremendous energy. While these stabilization methods have held lateral erosion or meandering movement of the river in check, the river has responded by diverting its lateral energy downward. This has caused a significant deepening of the river bends.

Sandbars on the inside of these bends formed points, commonly called point bars, which encroached into the navigation channel. The result has been the development of a severely narrow, deep, and swift navigation channel. The negative impacts of these river bendways create destruction and costs of great magnitude to both the navigation industry and the environment.

8. Environmental Impacts of River Bends. The U.S. spends millions of dollars each year dredging point bars in troublesome bends to keep the navigation channel open. This remedial measure only serves as a short, temporary cure. The river naturally replaces the sediment during high water events. Frequent dredging also puts unwanted strain on the environment by releasing unnatural levels of suspended sediment and toxins from the sediment.

Information on these impacts can be found at the US Army Corps of Engineers, St. Louis District web site, http://mvs-wc.mvs.usace.army.mil/arec/ "Applied River Engineering Center."

Excessive bankline erosion and overbank scour are phenomenon caused by river conditions existing in some bends. Although revetments usually protect the banklines, the bends are subjected to a tremendous amount of force from excessive currents. These conditions may lead to serious bankline and overbank erosion resulting in loss of adjacent wetlands and farmland.

In some bends, dikes were constructed on the sandbar side of the bendway in an attempt to improve the navigation channel. The least tern, a federally-endangered species, uses many of these sandbars as nesting habitat. Dike construction on these sandbars may endanger or even eliminate the bendway's natural habitat.

C. RESOURCE OPPORTUNITIES

Despite some of the negative impacts associated with river training structures on river morphology, several aspects of their physical impacts on the local ecology give promise to habitat restoration on the UMR.

The aquatic community found near a training structure is relatively diverse, owing to the range of available habitat types within a comparatively small area. The St. Louis District contracted a study which analyzed invertebrate populations on the dikes and in the surrounding riverbed to determine if chevron dikes were providing macroinvertebrate habitat. The macroinvertebrate assemblages were compared between the interior dike rock, exterior dike rock, interior soft substrate, and the surrounding soft substrate. No unionids (mussels) were found due to previous open water dredge disposal in the area. However, the dikes and protected areas behind dikes were providing habitat for invertebrates and fish. Diversity and taxonomic richness was higher on dikes than in the surrounding soft substrates in all three years of the study (Ecological Specialists, Inc. 1997).

Sandheinrich and Atchison (1986) found dike (i.e., wingdams) fields provide a varied range of depths, substrates, and currents that increase habitat complexity and affect fish distributions and community diversity. The fish communities associated with dikes are diverse and may harbor more species than any other habitat within the main channels.

In addition, the St. Louis District is developing innovative designs for river training structures and modifications, which primarily serve to help maintain the navigation channel, but which can also enhance the river's habitat diversity when properly designed. These structures can alter hydrodynamic conditions, sediment transport regimes, water depth diversity, and habitat conditions.

D. HABITAT REHABILITATION AND ENHANCEMENT PROJECT (HREP) OBJECTIVES[1]

Harnessing the positive benefits from training structures fits nicely with the EMP goals and objectives outlined in the 2010 EMP Report to Congress (USACE, 2010). These structures' ability to alter hydrology and their physical character contribute to the overall diversity and conditions aquatic animals seek out for shelter and food.

Engineers and biologist who know how river training structures alter a river's physical dynamics can use this to design project features such as island creation and protection, scour holes, and slack water habitats. Section E describes various training structures, their application and benefits to habitat manipulation.

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[1] For a detailed explanation of the overall EMP vision, goals, and objectives, see Chapter 2, *Habitat Rehabilitation and Enhancement Projects.*

The 2010 EMP Report to Congress first described how river training structures meet the UMRS Environmental Objectives, specifically:

- Improve fish habitat and water quality by altering inflows and diversifying substrate thickness
- Stabilize eroding channels
- Reduce sediment load to backwaters by reducing flow velocities
- Maintain water temperature and provided rock substrate

E. RESTORATION OPPORTUNITIES USING RIVER TRAINING STRUCTURES

Training structures can be used to alter hydrodynamic conditions, the sediment transport regime, and ultimately habitat conditions on the UMRS. The impacts of channel training structures are most evident in the southern pools and the open river. They tend to cut off flow and increase sedimentation in side channel areas. Bank revetments prevent erosion and maintain a stable channel, but they have largely arrested new habitat creation. Wing dams also provide flow refugia and may support large concentrations of fish adapted to moderate flow. The rock revetment provides structure for dense aggregation of macro-invertebrates (Corps, 2000). St. Paul District's secondary channel restoration projects typically introduce flow into isolated channels or restrict flow into channels to reduce sedimentation and current velocity. The St. Louis District is pursuing projects to open the upper end of secondary channels, with the goal of introducing flow and improving water quality. Possibly, the most innovative secondary channel projects in development are being designed for Middle Mississippi River reaches not benefited from HREPs to date.

The remainder of Chapter 7 specifically discusses typical river training and side channel enhancement structure design/techniques in their own chapter subsection. The structures are:

1. Closure Structures
2. Wing Dam Notching
3. W-Weirs
4. Notched Closure Structures
5. L-Head Dikes
6. Spur Dikes
7. Alternating Dikes
8. Stepped Up Dikes
9. Bendway Weirs
10. Chevron Dikes & Blunt Nosed Chevrons
11. Off Bankline Revetment
12. Hard Points in Side-Channels
13. Vanes
14. Cross Vanes & Double Cross Vanes
15. J-Hook
16. Multiple Roundpoint Structures
17. Environmental Dredging
18. Longitudinal Peak Stone Toe
19. Bioengineering and Biotechnical Engineering
20. Wood Pile Structures
21. Root Wad Revetment
22. Woody Debris
23. Boulder Clusters
24. Fish Lunkers

1. Closure Structures. Closure structures are constructed across secondary channels to reduce floodplain conveyance and increase main channel depths. Rock (e.g., riprap) is used to partially or completely close secondary channels on the UMRS (photograph 7-1).

Photograph 7-1. Partial Closure Structure at the Weaver Bottoms Secondary Channel, Pool 5 (Jon Hendrickson, MVP 2005)

Secondary channel closure elevations should be constructed to the bankfull elevation or less. This increases the amount of floodplain conveyance occurring during flood events thereby restoring a more natural flow and sediment transport. If a secondary channel closure elevation is higher than the adjacent land (island or floodplain) high water events would increase erosive forces on the adjacent lands causing increased flood impacts.

There are two types of closure structures, the emerged closure structure and the submerged closure structure.

a. Submerged Closure Structures. Submerged secondary channel closures (i.e. those with a top elevation less than the low water surface elevation) may take the form of underwater rock sills higher than the bed of the channel, or they may consist of a rock liner whose purpose is to stabilize the channel and prevent further erosion and enlargement.

Engineering considerations regarding elevation, width, and side slope are similar to those for emerged structures and will not be repeated here. Calculating the flow over submerged structures is important, since they continuously convey water during all flow conditions. Safety for recreational craft is another consideration, since the location of these structures is not apparent to inexperienced boaters. Usually an elevation resulting in a depth of at least four feet during low flow conditions and a bottom width of 20 to 30 feet is specified based on recreational concerns.

b. Emerged Closure Structures. There are six types of emerged structures:

i. Top Elevation. Emerged secondary channel closures (i.e., those with a top elevation greater than the low water surface elevation) are generally constructed to the bankfull flood elevation or less. A low flow notch is often included in closure structures to allow continuous flow of water during low flow conditions and boat access.

ii. Width. Although emerged rock closure structures look similar to offshore rock mounds used for shoreline stabilization, they are usually constructed wider.

- The additional rock results in better self-healing capabilities in the event toe scour causes some sloughing off the downstream side of the structure.
- A structure having a width of about 12 feet at the water line presents the potential for construction access across the structure.
- A wider structure provides greater resistance against ice damage.

iii. Side Slopes. Side slopes vary from 1V:1.5H to 1V:4H. If the potential for ice damage exists, a flatter slope will increase the chance ice will deflect up and over the structure.

iv. Construction Materials. There are three materials, rock, earth, and wood, used in closure structure construction.

Rock. Since most closure structures are designed to be overtopped, they can experience significant hydraulic forces during flood events and therefore are usually constructed of rock. The rock gradations used for closure structures vary depending on the site conditions and must be well coordinated with the geotechnical and hydraulic engineers.

Earth. Experiments with vegetated earth closures, during the early years of the HREP program, were only partially successful, with several complete failures occurring. Because of this closure, structures are usually constructed of rock in the current program. If an earth structure is the best option, then the following engineering considerations should be considered.

- Adequate rock protection on the side slopes and possibly the top of the structure.
- Topsoil and vegetation should be established on the structure in places where rock is not used.
- A rock lined overflow section that is at a lower elevation than the remainder of the earth closure should be considered. This decreases the water surface differential over the earth portion of the structure during floods.

Wood. Trees and brush can be anchored to the bottom of a channel to cause sediment deposition to occur. This borrows on the technique developed over a hundred years ago, when pile dikes were constructed to develop a navigation channel. Sand transported along the channel settled in the piles due to increased friction and decreased current velocities further increasing the effectiveness of the structure. The main requirement for these structures to work is an adequate sediment load, which is not always the case in the northern pools of the UMRS.

v. Scour Hole Considerations. Although significant scour holes can develop on the downstream side of closure structures, these have rarely caused a significant problem for structure integrity. Usually the structures are constructed with enough rock so some self-healing can occur and even if there is some sloughing on the downstream side of the structure, most of the crest of the structure remains at the design elevation.

vi. Lessons Learned. The environmental objectives are applicable to all dike or closure designs, construction, and maintenance. These are:

- schedule construction and maintenance to avoid peak spawning seasons for aquatic biota;
- design and maintain dike fields to prolong the lifetime of the aquatic habitat (i.e., reduce sediment accretion);
- maintain abandoned channels open to the river; and
- self adjusting rock is important to heal scouring should that develop.

vii. Case Studies

Lake Chautauqua. A submerged rock closure structure was constructed at Liverpool Ditch with the top elevation at flat pool to minimize future side channel sedimentation by preventing excessive diversion of river flows. This structure has a 15-foot wide by 3.5-foot boat notch. Photograph 7-2 shows the structure's location between Liverpool Ditch and the Illinois River.

Photograph 7-2. Submerged Rock Closure Structure at Liverpool Ditch, Illinois River (August 2004)

Island 42, Pool 5. A layer of rock fill was placed along the main channel side of the earth closure across the inlet channel at an extremely steep slope (steeper than 1V:1.5H). During the 1997 flood this rock fill layer failed exposing bare earth. The mechanism was probably toe scour. Remedial action involved placing rock fill at a 1V:2.5H slope.

Indian Slough, Pool 4. This rock partial closure structure has been stable. The original slough has aggraded with sand as it adjusts to the reduced flow through this structure. The riffle pool structure, which consisted of two submerged rock weirs, has increased bathymetric diversity.

Lansing Big Lake. Earth closures were severely eroded during high water in the spring of 1995, and were replaced by rock closures in 1996. Shading by adjacent trees limited the growth of vegetation on the earth closures making them more vulnerable to erosion. An earth dike was breached in several locations during high water in the spring of 1995, causing erosion down to the original substrate. The PDT had tried to limit the loss of floodplain trees leaving trees very close to and in a few cases within the footprint of the dike. The tree shading limited growth of vegetation on the earth dike making them more vulnerable to erosion. Eddy action around trees adjacent to the dike also resulted in scour, though not a complete breach. These breaches were filled with a layer of riprap to create an overflow section. The elevation of the overflow section was lower than the elevation of the remaining earth dike so that flow would occur over the overflow section first reducing the head differential when the earth dike was overtopped. This has resulted in a stable structure that has been overtopped several times.

Spring Lake, Pool 5. This closure structure has been stable. An earth closure was constructed across a breach in the natural levee separating Spring Lake from an adjacent channel. The shorelines of this structure were stabilized with riprap at a 1V:3H slope on the channel side and 30-foot long rock groins on the Spring Lake side. Native grasses were planted along the top of the structure in 12 inches of topsoil.

Peterson Lake. Earth closures constructed across three small channels at the upper end of Peterson Lake were severely eroded during high water in the spring of 1996. These were replaced by rock structures that were set at a lower elevation than the adjacent channel banks. These structures have been relatively stable, though some remedial work has been required to patch small breaches at the point where the rock structures tie into the adjacent bank. The submerged and emerged rock structures that were constructed as part of the original project have been stable.

Long Lake, Pool 7. The earth berm constructed across the excavated channel into this lake was completely eroded during the 2001 flood. This caused the concrete water control structure to be undermined. As part of the repair of this project, a rock lined overflow channel was constructed to help decrease the head differential across this structure during flood events.

Pool 8 Islands, Phase II. Although this is primarily an island project, two rock sills, which essentially act as closure structures were constructed. Rock sill top widths were set at 13 feet in case a scour hole developed downstream of the rock sill. If scour would start to under-mine the downstream toe, the sill would be wide enough for some self-healing to occur without losing the entire crest of the structure. However, field reconnaissance indicates scour has not occurred at these rock sills. The rock sill top width probably could have been 10 feet and perhaps even less. The upstream slope of the sills was set at 1V:4H because of a concern with ice action. The flatter slope should result in ice riding up and over the structure rather than displacing rock.

Morgan Point Bendway Closure Structure, Arkansas. The $2.7 million project was designed to restore flows to the Morgan Point Bendway, which was cut off when the Wilbur D. Mills Dam was constructed. An overflow weir closure structure at the mouth of the bendway and a water supply pipeline from the dam was built.

2. Wing Dams Notching. Rock dams (also called dikes), running perpendicular to the shore, have long been used to guide the river and maintain the navigation channel. River engineers found simply by adding notches, the dikes continue to create navigation dimensions as well as support diverse habitats. Figures 7-1 and 7-2 show examples of notching.

Figure 7-1. Wing Dam Notching

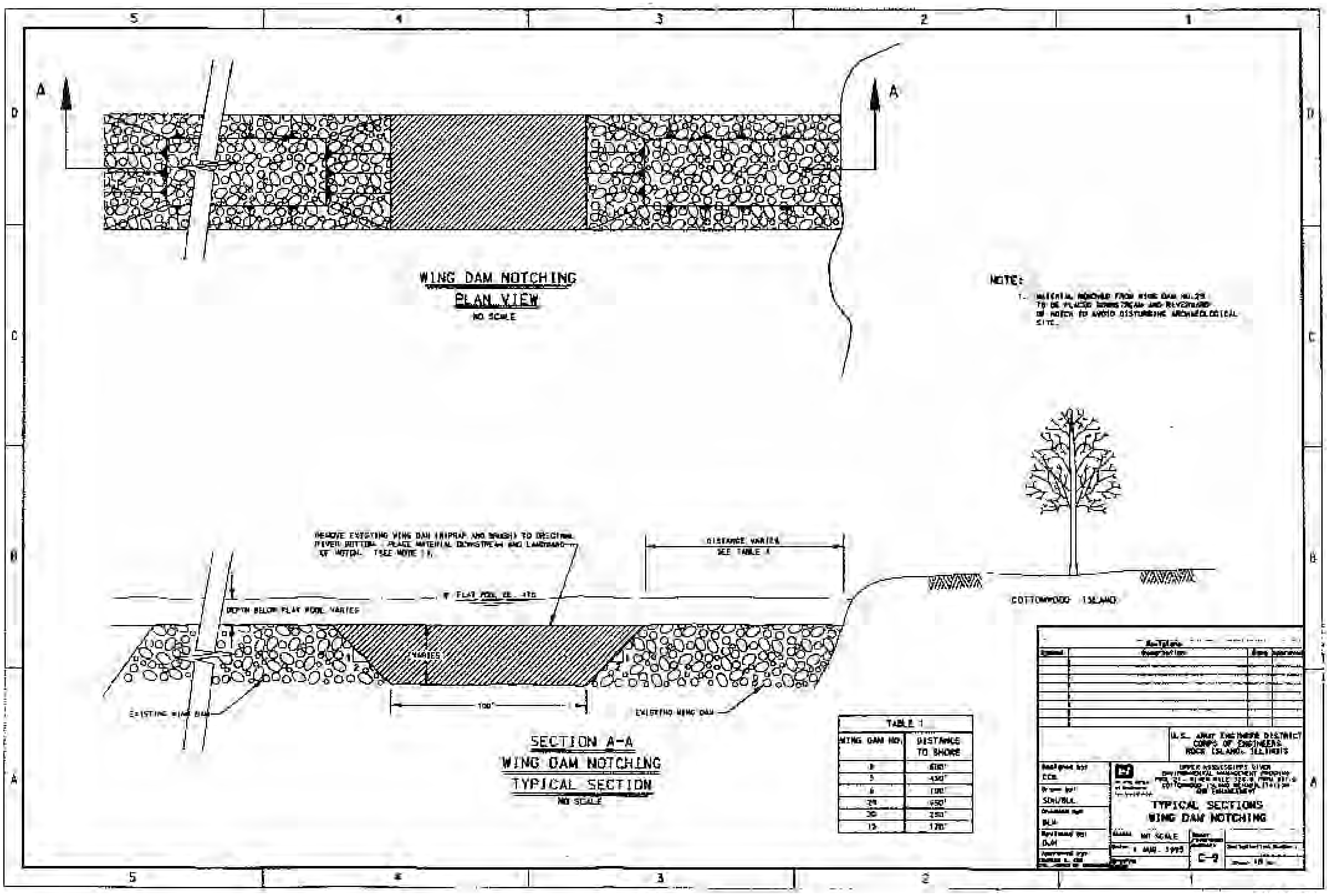


Figure 7-2. Wing Dam Notching – Typical Section

The river is allowed to move in and out between the notches creating all four of the primary river habitats. Sediment buildup forms small sandbars between each of the dikes. A variety of notch locations, sizes and widths can be used to create the optimum design. The overall result, however, is the creation of diverse environments by making a small but significant design modification.

The diversity of fish communities has been found to be slightly higher at notched dikes. The diversity of aquatic invertebrate was significantly greater at notched dikes. This seemingly can be attributed to the greater variety of habitat created below notched structures. The creation of small chutes within a dike field, the presence of submerged sandbars, and increased edge habitat are valuable forms of aquatic habitat diversity that benefit not only the fish community, but the macroinvertebrate community as well. The highest benthic invertebrate density, biomass, and number of taxa were found in gravel substrate samplers yielded nearly 27 times the number of macroinvertebrates than Ponar grab samples did from predominantly sand substrate near the dikes. (Hall, 1980)

Removed material placed downstream of the notch creates interstices and promotes invertebrate colonization, thus promoting fish foraging. Flow will increase in the vicinity of the notch, deepening the pool behind the wing dams. The change in flow at one wing dam may also stimulate an in-stream meander to the next wing dam. A meander would create deeper areas, attracting a more diverse benthic community and fishery. Burch et al. discussed notching emergent wing dams resulted in holes being eroded in the sediment downstream of the notch (1984). The wing dams in their study extended from the channel bottom to above normal water level (i.e., emerged wing dams).

The St. Paul District has experimented with wing dams for the purpose of creating scour holes on the downstream side. It is anticipated the increased bathymetric diversity was found to be more discernible where larger notches were constructed and where the wing dams extended above the surrounding river bottom a few feet as opposed to those locations where the wing dams were nearly flush with the surrounding river bottom.

In locations characterized generally depositional in nature and the notches in the wing dams are not discernible, this may indicate the notches may have been filled in the spring 2001 flood.

There may be a great deal of bed load moving through some of these main channel border areas. These areas are relatively unstable sandbars, depositing in one year or one part of the hydrograph and eroding during the next year or another part of the hydrograph. Scour holes and other bathymetric diversity developing in these areas may be temporal in nature.

The period of record is relatively short – 2 years between the notchings and the post-notching surveys. The changes may have been developed during the flood of 2001 and it may take additional time for any changes produced by the notches to be evident, (Hendrickson, 2005).

Burch et al., (1984) details a decision making process on notch location, and design. This technical manual is highly recommended resource.

a. Lessons Learned

- Rock size specification should be 400-lb. or larger rock, considering potential for interstitial spaces for critters or vary rock specification with expected hydraulic flow conditions versus sedimentation rates.
- Sizing/designing notches and other structures to naturally create plunge pools at higher flows providing 6 to 8 feet of deeper, stiller water during the normally lower flows more typical during overwintering periods.
- Monitor enough mussel beds upstream or downstream of wing dams being notched to satisfactorily assess and evaluate the extent of impacts, if any, on mussel abundance and diversity in the bed before and after notching.
- Various styles of notches and their bathymetric effects were studied by Brown (2205) in a laboratory.

b. Case Study

Cottonwood Island. Six wing dams were notched to provide flowing water habitat for fish and additional habitat and substrate for benthic and aquatic organisms. The notches were created by removing existing wing dam material to the original river bottom or a maximum of 10 feet below flat pool. Each notch was 100 feet long. Notches were staggered in anticipation that flow would increase in the vicinity of the notch, creating a scour hole behind the wing dams and stimulating a meander to the next wing dam (figure 7-3). Preliminary post-construction monitoring efforts indicate the formation of scour holes behind the wing dams and an increase in velocity at and below the notches (USACE, 2007)

Year 50 Target is to maintain velocities greater than or equal to 0.35, 0.5, and 0.4 feet per second at the following locations; 100 feet upstream of the notch, at the notch, and 100 feet downstream of the notch, respectively. Year 3 (2000) reported average velocities for Wing Dams No. 6 and No. 15 of 1.17 and 1.67 feet per second, respectively. Average velocity measurements at the notch and 100 feet downstream from the notch were considerably higher than those observed 100 feet upstream, which agrees with the results of similar studies reported by the Iowa Department of Natural Resources (USACE, 2007).

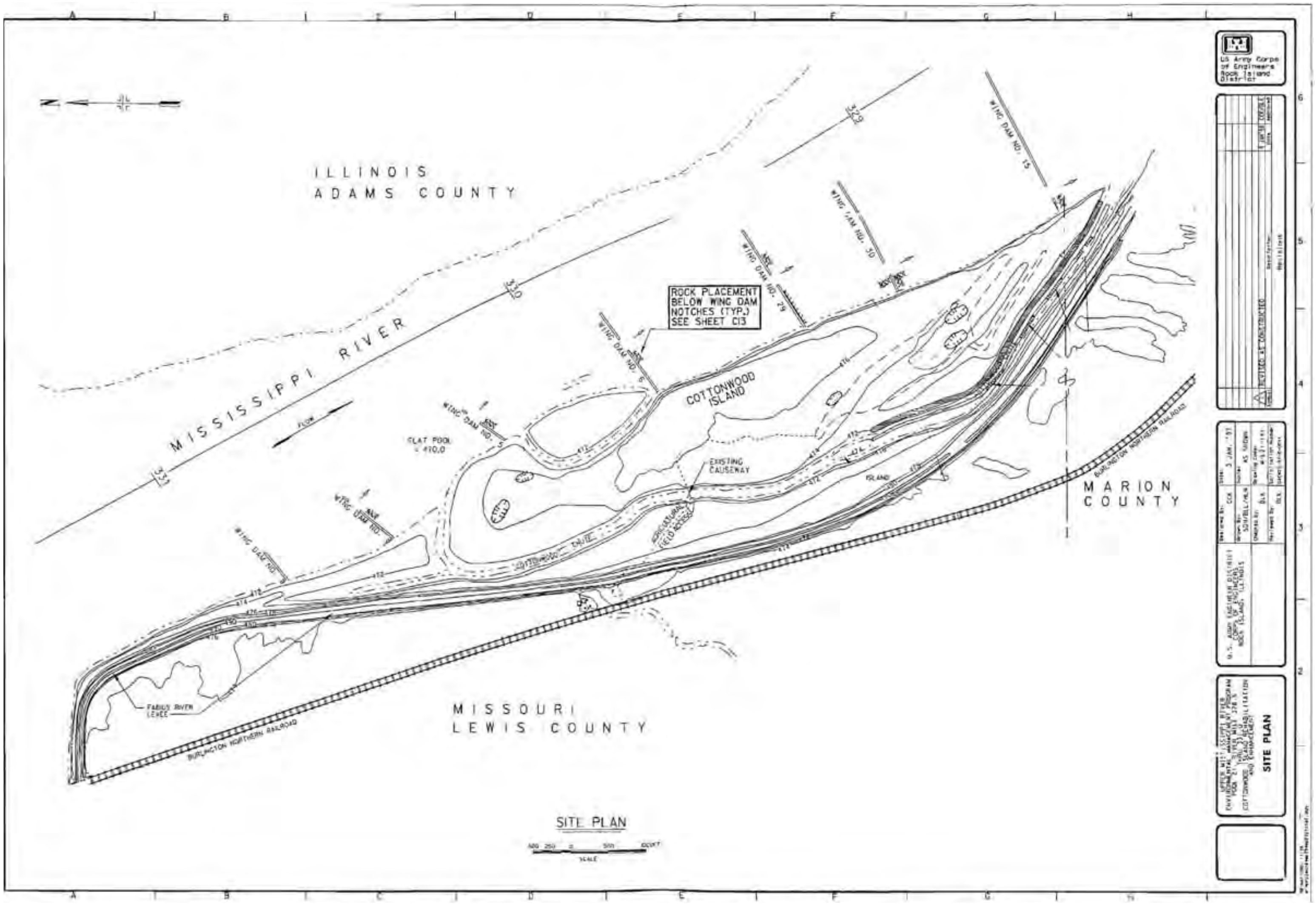


Figure 7-3. Cottonwood Island HREP; Wing Dam Notch Site Plan

3. W-Weirs. The design of the W-Weir (figure 7-4) was initially developed to resemble bedrock control channels on larger rivers. Various rock weirs installed across larger rivers for fish habitat, grade control and bank protection often create an unnatural and uniform “line of rocks” that detracts from visual values. The W-Weir is similar to a Cross-Vane in that both sides are vanes directed from the bankfull bank upstream toward the bed with similar departure angles. From the bed at ¼ and ¾ channel width, the crest of the weir rises in the downstream direction to the center of the bankfull channel creating two thalwegs. The objectives of the structure are to provide grade control on larger rivers, enhance fish habitat, provide recreational boating, stabilize stream banks, facilitate irrigation diversions, reduce bridge center pier and foundation scour, and increase sediment transport at bridge locations. Double W-Weirs are constructed on very wide rivers and/or where two center pier bridge designs (three cells) require protection (Rosgen, 1996).

a. Rock Size. Rock used for the construction of W-Weirs will meet the following size requirements, as shown in table 7-1. All units are shown in feet (ft) and pounds (lbs). Rock sizes apply to both Footer Rocks and Weir Rocks. The dry unit weight of each rock should be 150 lbs/cu ft or greater.

Table 7-1. W-Weir Rock Size

	A-axis	**B-axis**	**C-axis**
Minimum Size	4 feet	3 feet	2 feet
Maximum Size	8 feet	6 feet	5 feet

b. Construction Methods

- W-Weirs are constructed with two Rock Vanes on opposing sides of the stream channel forming the outside legs of the W-Weirs and two opposing vanes in the center of the channel to complete the W-Weir. W-Weirs may be staggered, such that one leg of the W-Weirs is offset either upstream or downstream of the opposite leg. The “W” shape is seen when viewing the W-Weirs from upstream looking downstream.

- The outside Rock Vane components shall extend to the streambed invert in an upstream direction forming the outside legs of the W-Weir. The inside legs of the W-Weir shall be constructed similar to a Rock Vane with the exception that the apex (joining point) of the inner legs is at an elevation that does not exceed ½ of the bankfull elevation.

- The W-Weirs shall be constructed so that adjoining rocks taper in an upstream direction (outside legs) from the bankfull elevation to the stream invert. The inside legs shall extend from the streambed invert in a downstream direction and shall be tapered to a point ½ the bankfull elevation. The elevation of the apex of the W-Weir may be adjusted as required or as directed by the Contract Officer/Project Engineer. The upstream end of the outside legs of the W-Weir is set at an angle of 20^{o} -30^{o} tangent to the curve.

- The downstream end of the outside legs of the W-Weir shall be keyed into the streambank at the bankfull elevation. The W-Weir shall be keyed a minimum of 8 feet into the streambank. The upstream end of the outside legs as well as the upstream end of the inside legs, will be keyed into the streambed at the invert elevation. The W-Weir legs shall be installed with a slope of 4 percent to 7 percent from the streambed invert to the bankfull or apex elevation.

- Footer Rocks shall be installed as shown in the Plans and Details and shall be firmly keyed into the streambed. All W-Weir rocks shall be placed behind footers. On larger streams, double footer rocks may be required to insure that the footer extends below the final invert of the plunge pool associated with the W-Weir.

- Rocks placed to construct the legs of the W-Weir shall be placed in a linear fashion so as to produce a sloping surface. Rock shall be placed with a tight, continuous surface contact between adjoining rock. Rock shall be placed so as to have no significant gap between adjoining rock.

- Rock shall be placed so as to have a final smooth surface along the top plane of the W-Weir. No rock shall protrude higher than the other rock in the W-Weir leg. A completed W-Weir has a smooth, continuous finish grade from the bankfull elevation to the streambed, and from the streambed to the apex.

- If applicable, stabilizing vegetation is seeded on top of the W-Weir.

- The Contractors shall upon completion of the work reshape the slopes and stream bottom to the specified elevations. All unsuitable and surplus rocks will be removed from the site.

c. Lessons Learned . None listed.

d. Case Studies. None listed.

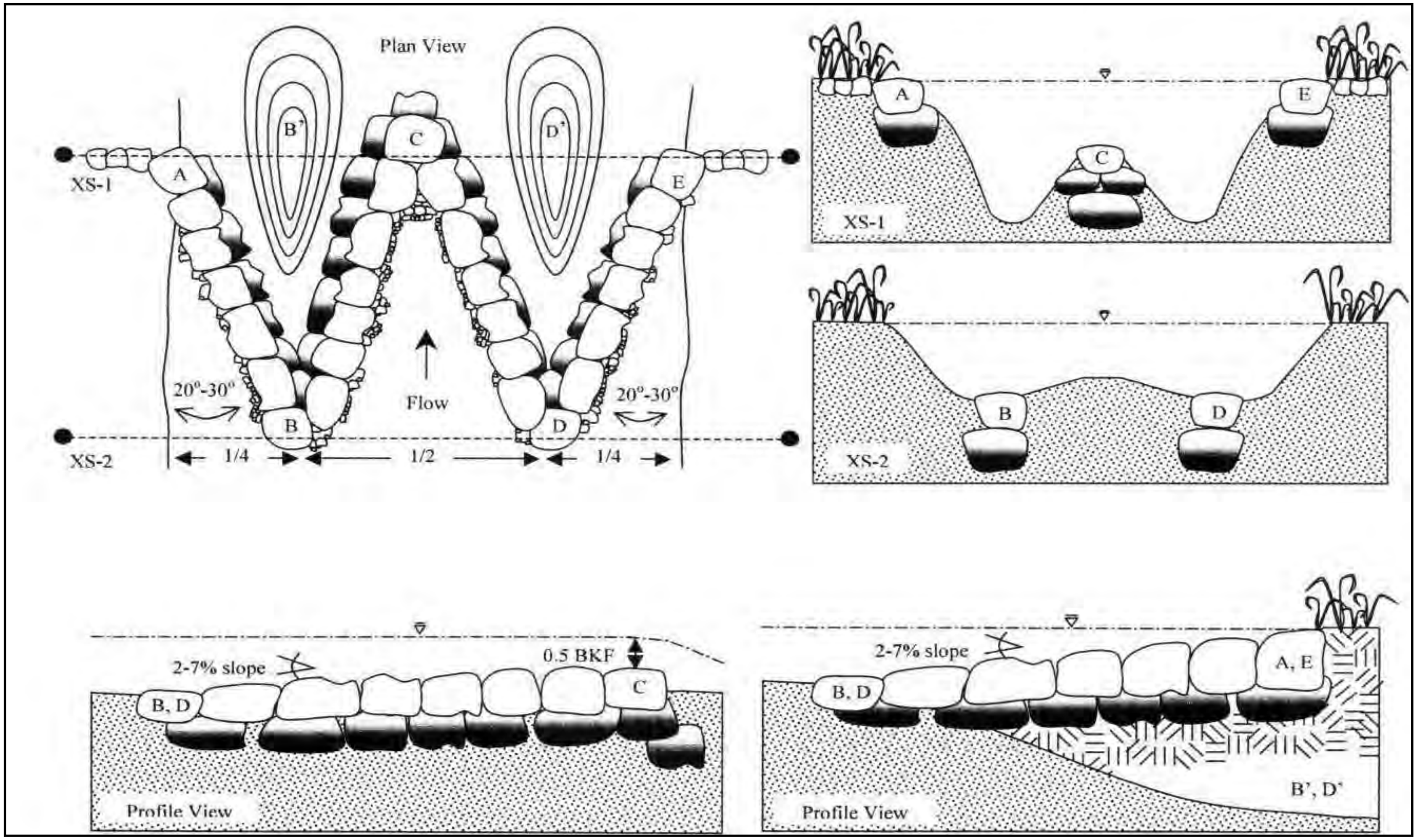


Figure 7-4. Plan, Cross Section, and Profile Views of the W-Weir (Rosgen, 2001)

4. Notched Closure Structures. Side channels are not used for navigation, but are valuable environmental areas. Traditionally these side channels were closed with rock structures to divert the flow into the main channel. While improving navigation, this process tends to fill the side channels with sediment and convert aquatic habitat to terrestrial habitat.

Notching a closure structure tends to keep the side channels from being filled with sedimentation. These structures form areas of deep water and shallow water creating a diversity of habitat, attracting different species of fish. (figure 7-5).

a. Lessons Learned: Notches should be able to accommodate pleasure boat traffic. The notch's bottom elevation should be at least 3.5 feet below flat pool elevation.

All closing dams should have bankline protection on both shorelines. Many closing dams create eddies on the downstream side of the structure and will scour the adjacent river banks.

b. Case Studies None listed.

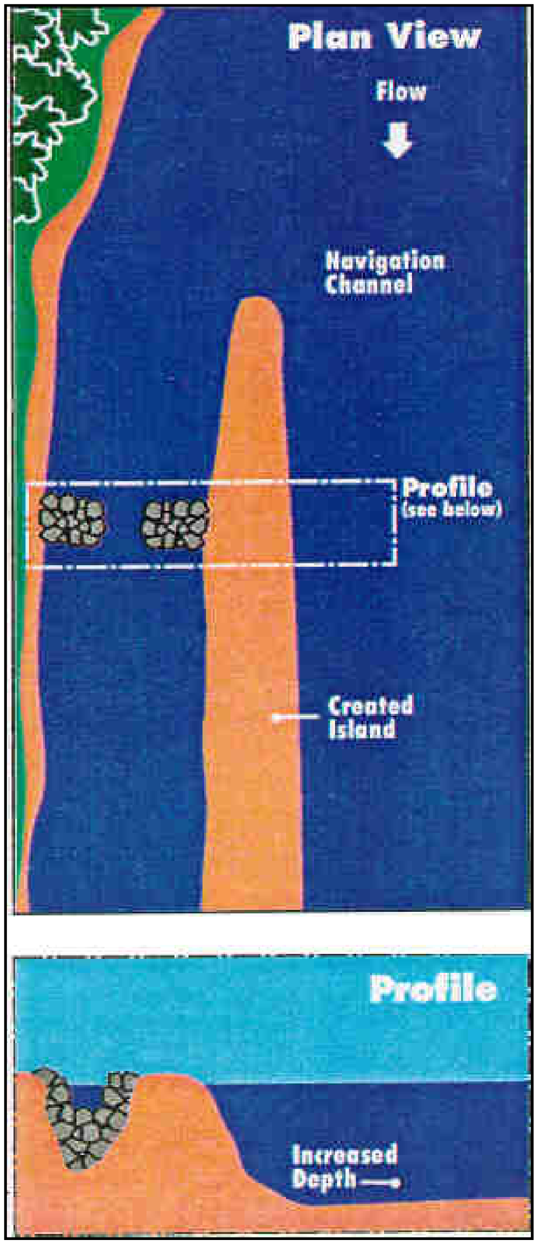


Figure 7-5. Notched Closure Structures

5. L-Head Dikes. The L-Head is a training dike with a perpendicular dike structure attached at the channel end creating an L shape. The attached dike structure is usually lower in elevation (e.g. 1-5 feet). The purpose of this structure is to control scour patterns at the training dike's riverward end for channel improvement. Photograph 7-3 shows an example.

Photograph 7-3. L-Head Dike, Marquette Chute, near Middle Mississippi River Mile 51.0L

Dike fields are constructed to change the morphology of natural alluvial waterways. Dike fields accomplish this by stabilizing the position of bars, controlling flow through secondary channels, and reducing channel width over some range of discharges. Dike fields are normally used in conjunction with revetments to develop and stabilize the channel.

Dike fields change river morphology by decreasing the channel width in the vicinity of the dike fields, decreasing the surface area of the waterway, increasing the depths through bed degradation, and sometimes shifting the channel position. As the flow is realigned and/or constricted, the bed is scoured by locally higher velocities. Decreased velocity within the dike field leads to accretion of sediment in this area.

Effects of low-elevation dikes on habitat diversity occur through changes in water depth and sediment characteristics. These changes are determined by the behavior of the flow over the crests of the dikes. Local flow accelerations have been observed over submerged dikes. These accelerated flows usually develop a scour hole immediately downstream of the dike with a submerged bar forming downstream of the hole (Burke and Robinson 1979). Lower elevation dikes tend to accrete larger sediment deposits within the dike field than higher elevation dikes. However, it has been found that the higher the dike, the more rapidly secondary channels and backwaters filled with sediment and the more rapidly a bar was produced below the dike. The location has more influence on the rate and extent of sediment accretion than dike design. A dike built in a zone of deposition will be likely to accrete sediment regardless of its crest elevation.

Low elevation dikes have beneficial impacts on habitat diversity through the creation of the deep scour holes. These holes provide important shelter for fish during the winter low-flow season. The submerged sandbars provide shallow-water habitat which provides nursery areas for many fish species. The Environmental Work Team (1981) found smallmouth bass, northern pike, and walleye associated with submerged dikes on the upper Mississippi River. Dikes less than 5 ft in depth (corrected to operating pool levels) had significantly higher fish catch than deeper dikes. Dikes on concave sides of bends had significantly higher catch and number of species than dikes on convex sides of bends.

a. Lessons Learned. Adverse effects are related to sediment accretion, alterations in river depth and stage, reduction in wetted edge, locally increased main channel velocities, and a reduction in slack water habitat caused by closure and subsequent sedimentation of sloughs, chutes, and secondary channels.

b. Case Studies

Kansas River at Eudora Bend, KS

Monkey Run at Arcade, NY

Eighteen Mile Creek Salmon Stream Restoration, Newfane, NY

6. Spur Dikes. Spur Dikes are used in river training as contraction works to establish normal channel width; to direct the axis of flow; to promote scour and sediment deposition where required; and to trap bedload to build up new banks. Although less effective than training walls in rivers carrying small bed loads and in channels having steep gradients and swift currents, they are often more economical than longitudinal works since material is required to protect the bank. Figure 7-6 shows an example of spur dikes.

Spur dike performance is enhanced when there are several dikes in a series. Spur dike performance also relies on placing the crest of each dike at about the same elevation with respect to a low-water profile and position most of the dikes in a system generally normal (perpendicular) to flow.

Franco (1967) evaluated dike performance and developed some parameters considered in general dike construction. These parameters should be considered in the spur dike planning stage.

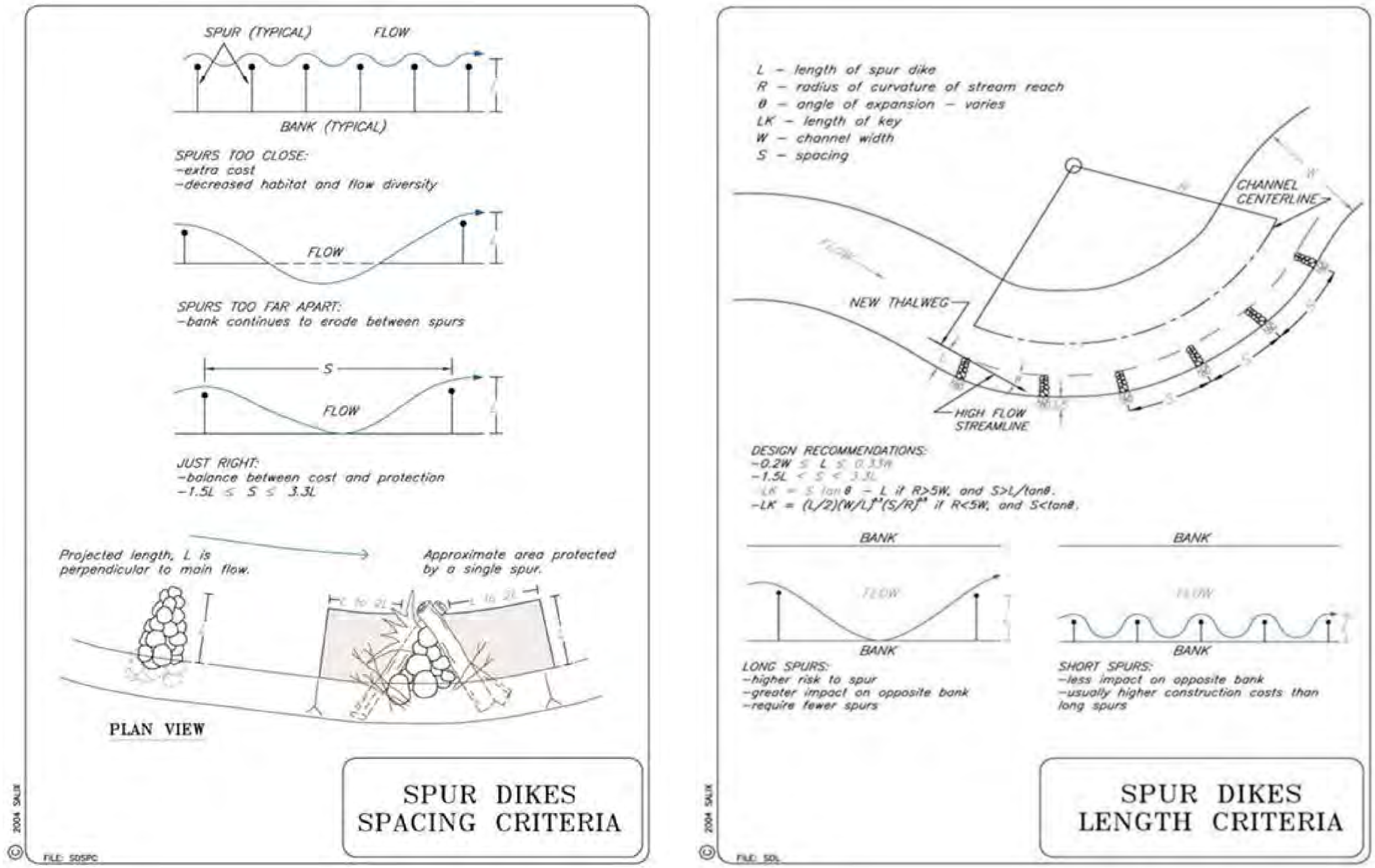


Figure 7-6. Spur Dikes (Source: www.e-senss.com)

a. Lessons Learned

- Spur Dike spacing is critical. If the spacing is to close, the depositional areas will not form and if the spacing is too far, bank erosion is possible between the structures.
- An important factor to be considered in dike design is the movement of currents near and within the dike field.
- Dike systems having the stepped-down effect are more effective than dike systems with all dikes level. Dikes constructed with their crests level with respect to each other are more effective than dikes having the stepped-up effect.
- Sloping-crest dikes can be designed to be as effective as level-crest dikes.
- The amount of dredging required to produce project dimensions is inversely proportional to dike elevation.
- There is a greater tendency for dikes angled downstream to be flanked near the bank end than dikes angled upstream, and for level-crest dikes to be flanked near bank end than sloping-crest dikes.
- Level-crest dikes should be placed normal to the flow or angled downstream. Sloping-crest dikes should be placed normal or angled upstream.
- Channel width influences the use of bendway weirs and other spur-type countermeasures. On smaller streams (<75 m (250 feet) wide), flow constriction resulting from the use of spurs may cause erosion of the opposite bank. However, spurs can be used on small channels where the purpose is to shift the location of the channel.

7. Alternating Dikes. Alternating dikes can typically be used in side channels that are long and straight. The dikes are placed along both banklines in an alternating configuration. The design creates a sinuous flow pattern in areas previously having homogeneous flow. The river bed is also altered with the development of scour holes off the ends of each dike and sand bars along the banklines upstream and downstream of each structure. Photographs 7-4 and 7-5 show examples of alternating dikes.

The altered flow patterns typically put additional flow along the bankline, opposite each dike which induces erosional tendencies. Therefore, these privately owned areas, there is a presence of infrastructure, or if lateral movement of the bankline is simply not desired, the bankline should be armored with stone. If the land is publicly owned, lateral movement of the bankline could produce a sinuous planform if allowed to erode naturally.

The design of alternating dikes is usually initiated with the use of a hydraulic sediment response model but keep in mind this is just one model. Model types should be dictated by data and needs of the project. The model is typically used to determine spacing, length, and height of each structure. Each dike is usually constructed to a maximum of 1/3 of the overall side channel width and is keyed into the bankline using standard design parameters for dike construction. Revetment is placed for a short distance both upstream and downstream of the structure to protect it from flanking. In some cases, revetment can be placed along the opposite bankline from the dike head to prevent channel meandering.

Photograph 7-4. Alternating Dikes

Photograph 7-5. Alternating Dikes

a. Lessons Learned. Most dikes built along the main channel border are typically ½ to 2/3 bankfull height. This elevation is an effective height to produce the desired riverbed scour and channel formation. However, most side channels in the Mississippi River flow less frequently and with less energy than the main channel. Bed elevations are usually much higher than the main channel. Dikes built in side channels to typical elevations used in the main channel have not always created the desired effects. Therefore, for maximum effectiveness, alternating dikes are typically constructed to an elevation close to the top-of-bank elevation. This elevation utilizes the maximum amount of energy available in the side channel during bankfull and flood flows to scour the bed and create the desired flow patterns.

b. Case Study

Santa Fe Cute. The St. Louis District micro modeled Sante Fe Chute in 1996 to study various methods of rehabilitation. This project is shown in photograph 7-6. After it was discovered that removing the closure structure at the upper end of the side channel would increase deposition in the chute, designs were considered that would make use of the existing energy in the side channel to create bathymetric diversity. It was discovered that alternating dikes could have a unique effect. Although it was recommended to construct 9 dikes at elevation top-of-bank only 6 dikes were constructed in 1997 to an elevation of ½ bankfull due to funding limitations.

Photograph 7-6. Santa Fe Chute Alternating Dikes

After monitoring the riverbed, it was determined although the design had shown some indication that it was producing the desired effects, it still was not what the designers had envisioned. Therefore, once adequate funding was received, the dikes were raised to the original design elevation and the remaining dikes were constructed. The side channel is now developing the bed forms originally predicted by the micro model. Scour holes are developing off the ends of the upstream dikes first as the bed development works in the downstream direction. Due to low frequency of flow in the side channel, the bed development has progressed slowly. The revetment along both banklines and adjacent the privately owned land is providing the necessary protection.

8. Stepped Up Dikes. Stepped-up dike fields of various elevations provide an additional element of riverine habitat diversity. They counteract sediment deposition, thereby preventing the conversion of aquatic environment into terrestrial. In the stepped-up dike configuration, each dike in sequence rises two feet higher than the previous upstream dike. This approach utilizes the river's energy to change the sediment deposits as the water level rises and falls (figure 7-7).

Dike fields are constructed to change the morphology of natural alluvial waterways. Dike fields accomplish this by stabilizing the position of bars, controlling flow through secondary channels, and reducing channel width over some range of discharges. Dike fields are normally used in conjunction with revetments to develop and stabilize the channel.

Dike fields change river morphology by decreasing the channel width in the vicinity of the dike fields, decreasing the surface area of the waterway, increasing the depths through bed degradation, and sometimes shifting the channel position. As the flow is realigned and/or constricted, the bed is scoured by locally higher velocities. Decreased velocity within the dike field leads to accretion of sediment in this area.

Beneficial environmental effects are related to the diversity of substrates, depths, and velocities created by the dike fields and often provide a diverse habitat with a relatively high level of biological activity. Adverse effects are related to sediment accretion, alterations in river depth and stage, reduction in wetted edge, locally increased main channel velocities, and a reduction in slack water habitat caused by closure and subsequent sedimentation of sloughs, chutes, and secondary channels.

Figure 7-7. Stepped Up Dikes

a. Lessons Learned. None listed.

9. Bendway Weirs. The bendway weir is a low level, totally submerged rock structure positioned from the outside bankline of the river bend and angled upstream toward the flow. These underwater structures extend directly into the navigation channel underneath passing tows. Their unique position and alignment alter the river's spiraling, secondary currents in a manner which shifts the currents away from the outside bankline. This controls excessive channel deepening and reduces adjacent riverbank erosion on the outside bendway. Because excessive river depths are controlled, the opposite side of the riverbank is widened naturally. This results in a wider and safer navigation channel through the bend without the need for periodic maintenance dredging. The bendway weir also eliminates the need for dikes to be constructed on the inside of the bendway therefore protecting the natural beauty and habitat of this sensitive environment (Davenroy, 1990).

The bendway weirs have not only provided navigation benefits, but many significant environmental benefits as well. A wider and more smoothly aligned navigation channel has resulted so traditional above-water dikes will no longer be built on the sandbars. Nesting habitat for the Least Tern, an endangered bird species is thus left largely undisturbed. Bendway Weir fields have also proven to provide habitat for a number of fish species. These environmental reefs have created diversity in the river bed and flow patterns in areas that were once narrow, deep, and swift. Monitoring efforts have shown that the federally-endangered pallid sturgeon use the weir fields for their habitat. Figure 7-8 shows bendway weirs.

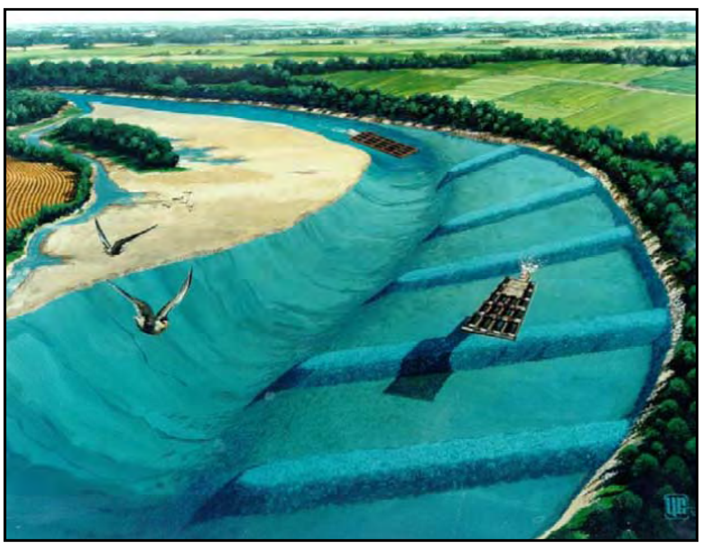


Figure 7-8. Bendway Weirs

The Missouri Department of Conservation tested the diversity in habitats surrounding a test section of bendway weir. Their raw data showed a total of 4,512 fish and 45 different species used the test site's bendway weir. They found an increase in diversity and numbers of micro-invertebrates. To a lesser degree, fish communities were also found to have greater diversity. In addition, the larger problem of aquatic environment becoming terrestrial was resolved. The river channel is maintained, structures are basically self-maintained and biological diversity has increased. Figures 7-9 and 7-10 show the functions of a bendway weir.

a. Lessons Learned. When placing weirs, construct downstream to upstream and it is critical to place the structures at an upstream angle of 30°. The design must consider the angle at which flow enters the bend; particularly in tight bends make sure the angle of attack is not through the weir field.

b. Case Study

Bendway Weirs. Nearly 200 weirs have been placed in the Mississippi River since 1990. The St. Louis District has a website (http://www.mvs.usace.army.mil/arec/reports_bendwayweirs.html) that provides a very comprehensive and detailed presentation of the development and application of bendway weirs. This reference provides an excellent source of design information for river engineers in the use of bendway weirs in a navigation channel.

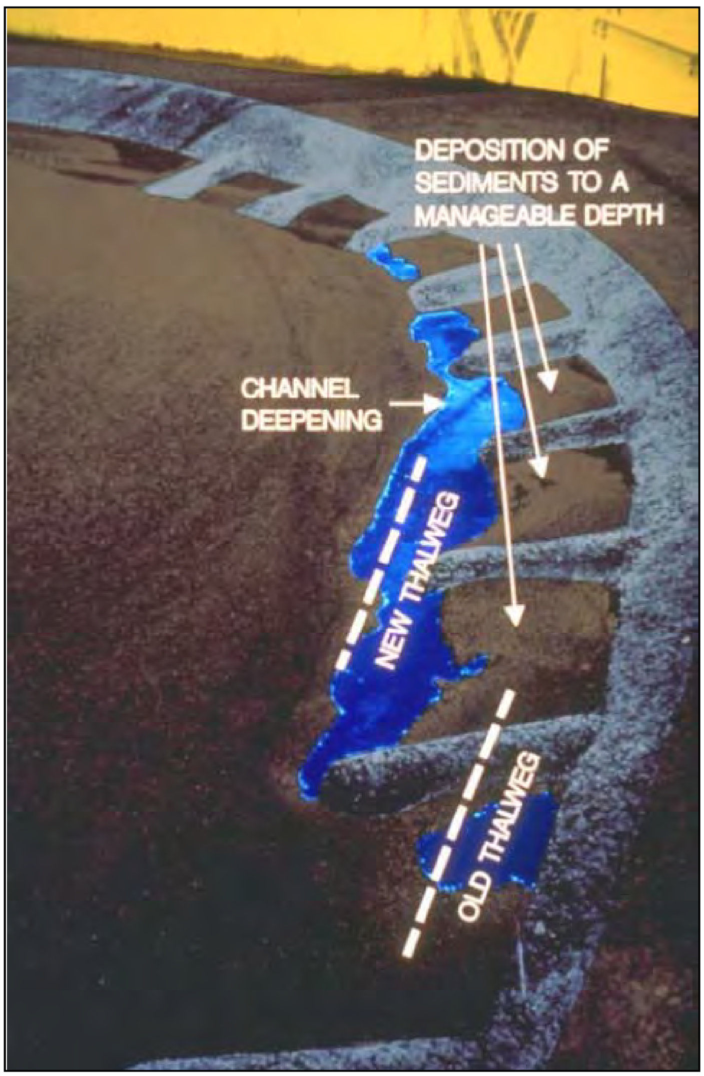


Figure 7-9 Bendway Weirs: Functions

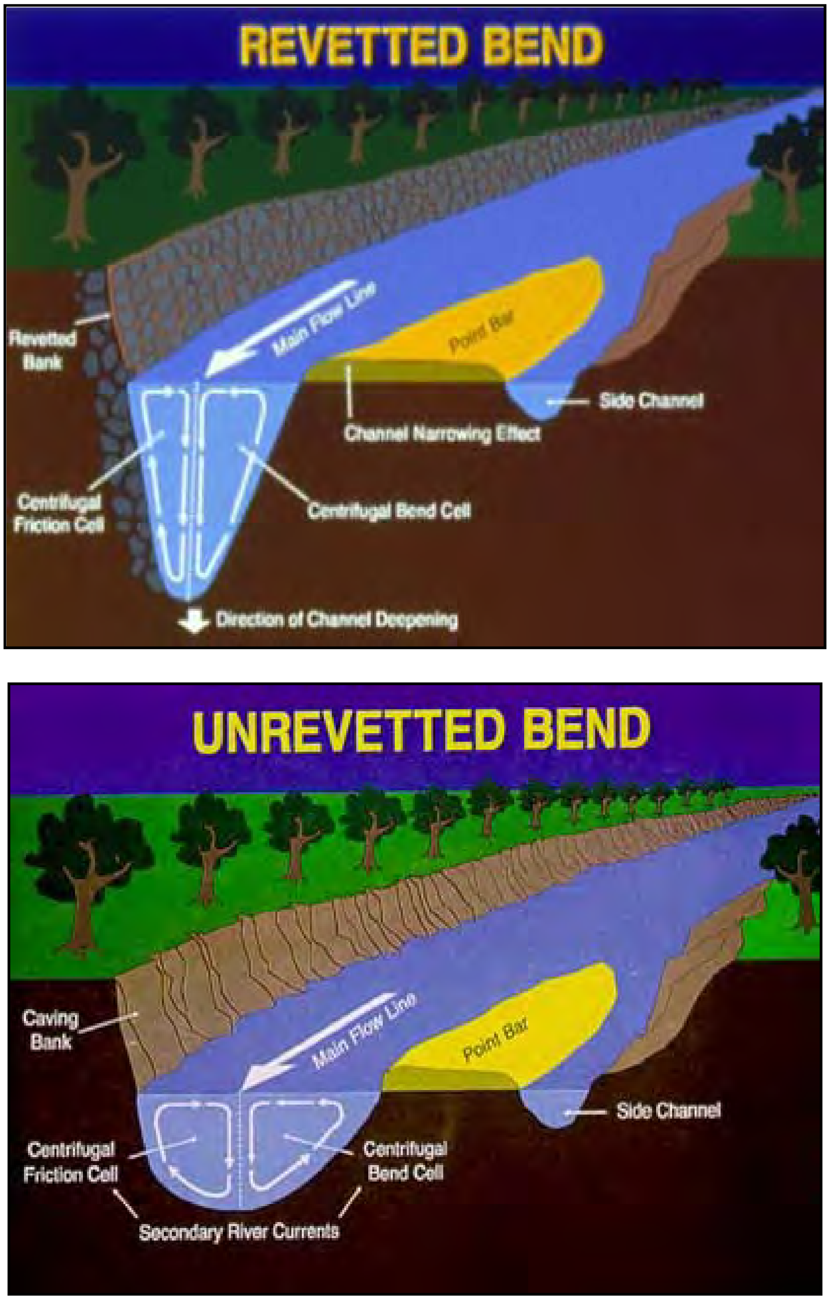


Figure 7-10. Bendway Weirs: Revetted and Unrevetted Bends

10. Chevron Dikes and Blunt Nosed Chevrons. Chevrons usually are not attached to the shoreline like the typical wingdam. All chevrons are V- or U-shaped rock structures pointing upstream. Not only do chevrons divert river flow like a wingdam, toward the main channel, they also create several different types of river habitat, with variable depth and flow velocities.

All types of chevrons are typically built above normal flat pool elevation to a 2-year flood elevation. River flows overtopping the structures during high water periods create a large scour hole inside of the chevron just downstream of the structure's apex. Downstream of this area the reshaped material deposits create a shallow bar.

The rock dike substrate may provide habitat for epilithic (rock dwelling or attached to rock) macroinvertebrates capable of colonizing in very high densities and providing an important food source for fish. Chevrons create habitat heterogeneity and appear to increase invertebrate abundance and diversity (Ecological Specialists, Inc. 1997) and provide useful and valuable habitat for a large variety of riverine fishes (Atwood 1997). Although this study investigated revetments, similar rock and hydraulic configurations at chevrons should create similar biological responses.

After the flows drop below the crest of the structure, the scour hole formed at high flow becomes an area of deep slack water. This environment is very conducive to the needs of overwintering fish and provides the ideal conditions for a juvenile and larval fish nursery. The potential plant life established along the wetted edges and uneven rock structure would provide good escape cover and foraging habitat for young fish.

The scoured material usually forms an island or builds on an existing island (in the case of a blunt nose chevron) immediately downstream of the structure. The islands encourage the development of variety of river habitats.

There are two types of chevrons - chevron dikes and blunt nose chevrons. Chevron dikes generally are used for navigation purposes whereby water is diverted towards the navigation channel for channel maintenance purposes. Blunt nose chevrons are used to protect the head end of islands from erosion.

a. Chevron Dikes. A chevron dike is a navigation structure that reduces dredging and improves river habitat. These structures are placed in the shallow side of the river channel pointing upstream. They are designed to push water towards the navigation channel. Sometimes when dredging is needed to improve the main navigation channel, dredged sediment can be deposited behind the chevron dike forming an island. These islands are important in the lower portions of pools where most of the historic island have been lost due to deepening the pools and erosion.

Chevrons are typically used in wider reaches of the river where a flow split is desired (photographs 7-7 and 7-8). A series of chevrons can be positioned to split flow between a side channel and the main channel. Controlling the flow into the backwater areas helps protect the natural existing bankline. Additionally, eddies created by the structure erode pools on the downstream side of the chevrons. These deep pools provide overwintering habitat for fish.

Photograph 7-7. A Series of Chevron Dikes on the Mississippi River

Photograph 7-8. A Series of Chevrons Aligned To Split Flow Between the Main Channel and a Side Channel, While Protecting the Existing Shoreline

b. Bluntnose Chevrons. Bluntnose, or bull nose, chevrons are designed to protect the nose of the island and the sharply vertical bankline (figure 7-11). Typical chevron design dimensions are discussed in the Gardner Division Case Study, page 7-32, provides typical chevron design dimensions). Original rock armor has eroded exposing soft nose which is eroding. Chevron ends tied in to armor bankline due to excessive cost for flattening slope. Backwater channel side left open to provide slow waters providing fish habitat. The design was originally to fill area in with dredged material, but that feature was dropped. Large (600 to 1200 lb) rock was desired, but logistical difficulties necessitated smaller, 400 lb rip-rap to be used. Chevrons upstream of Cottonwood Island are shown in photograph 7-9.

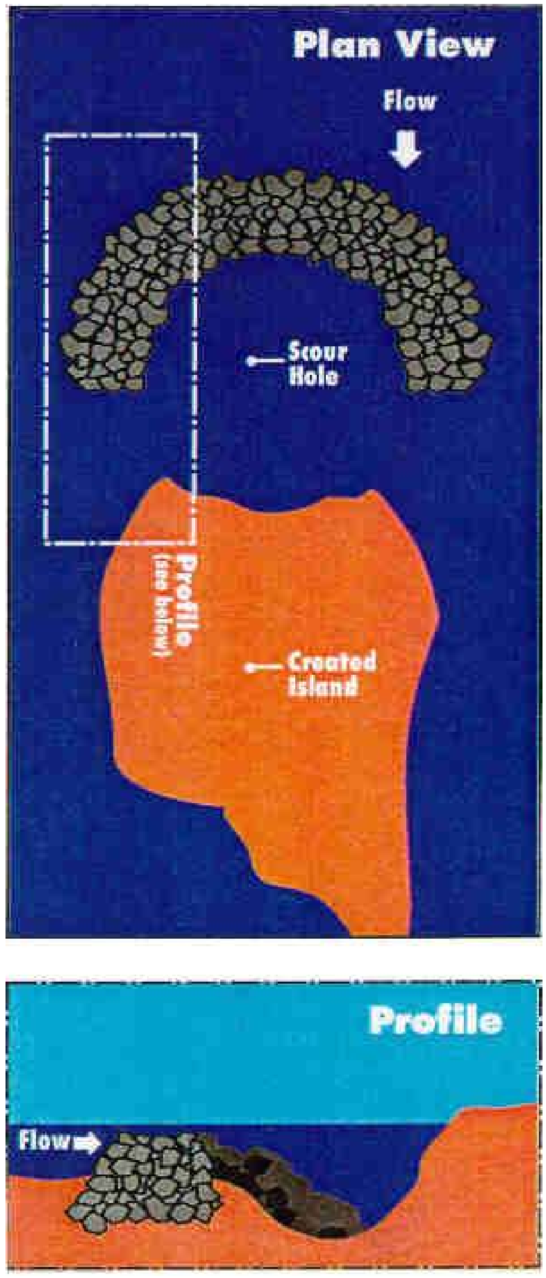


Figure 7-11. A Blunt Nosed Chevron Above an Island

Photograph 7-9. Cottonwood Island Chevrons

c. Lessons Learned. The first three experimental chevrons were constructed in Pool 24 near RM 290 in 1993 solely for the purpose of protecting dredged material. Initial monitoring of the chevrons showed they had immense environmental benefits by creating an abundance and variety of aquatic habitat (Ecological Specialists, Inc. 1997). Since then, these chevrons as well as three additional chevrons near URM 266 have been extensively monitored. Fifty-one fish species and a highly diverse group of macro invertebrates have been collected in and around the structures. The 8 years of data also show a high presence of young of the year and juvenile fishes inside of the structures, which suggest the structures are being used as nursery habitat. The data also shows the outside edges of the chevrons are providing excellent habitat for quality-sized catfish. Catch rates inside the chevron have been more than double the catch rates outside of the structures. Vegetation colonization, very favorable water quality conditions, and wading bird using the islands have also been documented.

The physical data collected in and around the structures show extensive depth, velocity, and substrate diversity which usually translates into habitat diversity. The structures create several different types of river habitat, with variable depth and flow velocities, and with multiple wetted edges or wetted perimeters where plant life can flourish.

Training structure work is commonly completed using large deck mounted cranes and rock barges. This work is usually completed in areas normally shallower than the main 9-foot channel which may make mobilization and demobilization a challenge. Construction should be scheduled at water levels conducive to mobilization to the project site.

d. Case Studies - Chevrons

St. Louis Harbor. Chevrons work better when used in a series. Bank revetment is typically needed on the near back of the structures. They are typically built at +2 feet above normal pool.

Gardner Division (LaGrange Island, Pool 21, constructed 2005). The initial layout of this bluntnose chevron was created by following previously deposited rock located on or near the head of LaGrange Island as part of the 6-foot navigation project (photographs 7-10 and 7-11 and figure 7-12). The height of the chevron was determined by viewing previously-built chevrons from the St. Louis District and reviewing the height of nearby closing dam and wing dam structures. The bankline next to the tieback eroded away and the head of LaGrange was still eroding. Improvements include increasing the tieback area to at least 300 linear feet and increasing the height of the chevron (figure 7-13).

Photograph 7-10. LaGrange Island Bluntnose Chevron in 2011

Photograph 7-11. LaGrange Island Bluntnose Chevron Rock Placement, Looking South East – August 2005

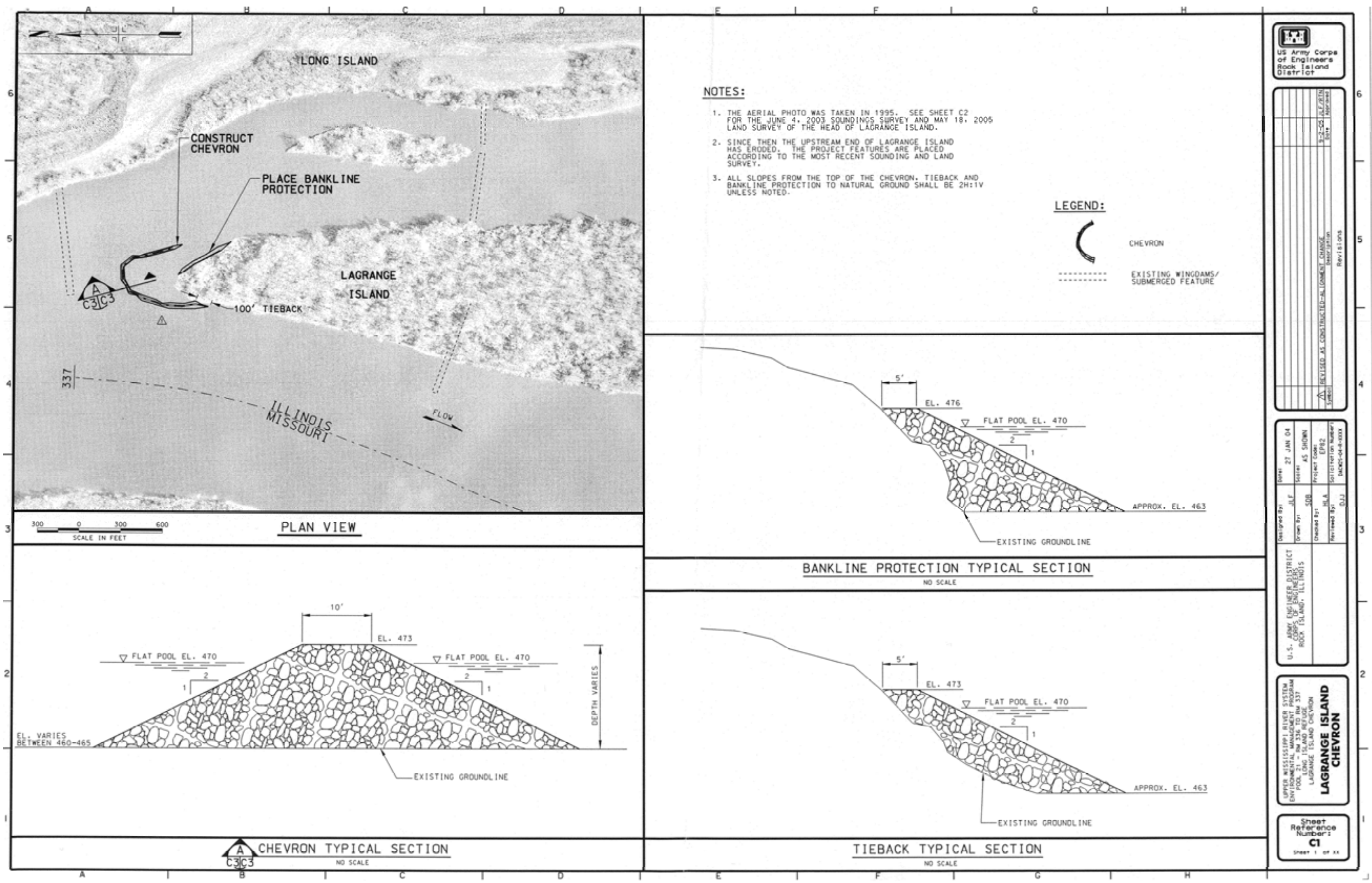


Figure 7-12. LaGrange Island Blunt Nose Chevron Design – Typical Sections

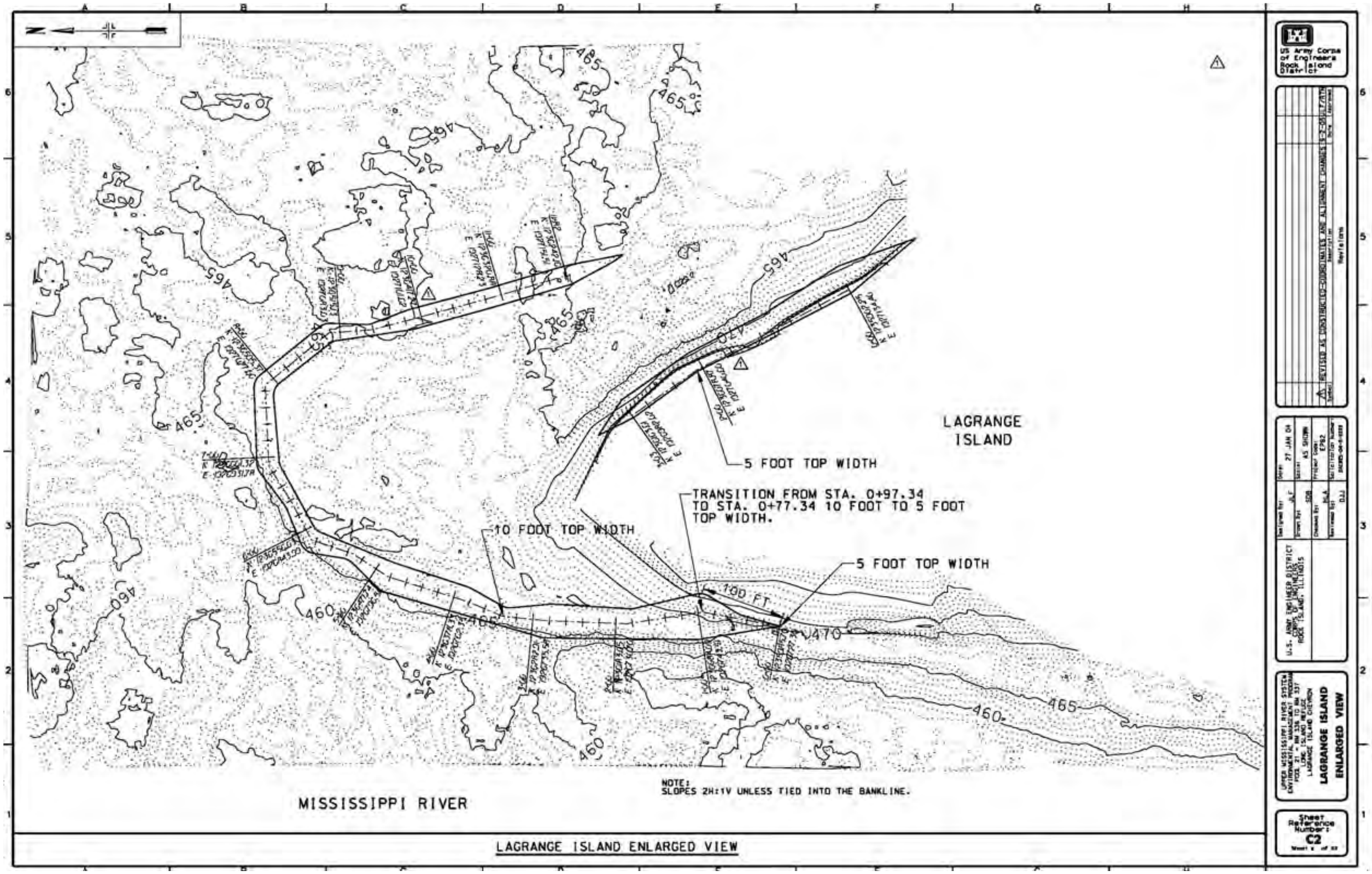


Figure 7-13. LaGrange Island Blunt Nose Chevron Design - Overview

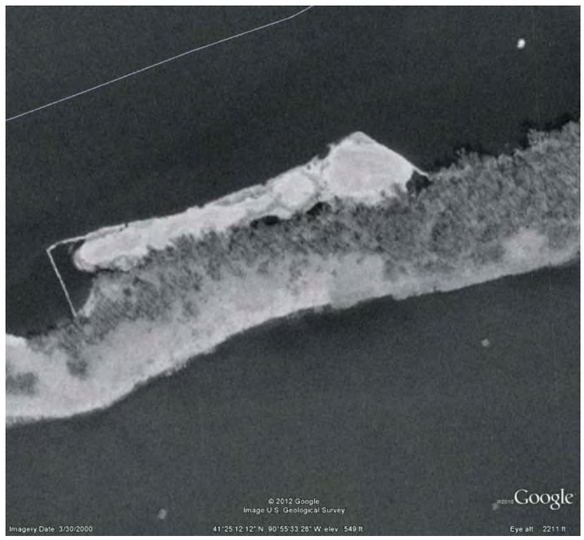
11. Off-Bankline Revetment. In areas where the caving river bank is on the shallow side of the river, there is a greater flexibility to design alternative solutions. By placing a parallel structure of stone off the bankline, erosion is reduced and diverse habitats are maintained. In some areas, the revetment is notched allowing fish to move between the fast water and the slow water easily. The areas between the revetments and the bank line are considered to be prime fishing locations by both commercial and recreational fishermen (figure 7-14).

Figure 7-14. Off-Bankline Revetment

a. Lessons Learned. None listed.

b. Case Study

Wing Dam Improvements at Hershey Chute, RM 461.5 (constructed mid 1990s)**.** The Rock Island District has a chronic dredge cut between RM 461.0 and 463.8 in Pool 16 of the Mississippi River. The District constructed rock revetments adjacent to a narrow piece of land separating the main river channel and the Andalusia Island HREP project. This project restored a backwater marsh important to migrating waterfowl. The revetments served three purposes. Initially the protected area was used by fish for a spawning area. Eventually the District used it as a dredge material placement site. The rock revetment also protected the narrow piece of land, from erosion, thereby protecting the habitat behind the island (photographs7-12 and 7-13).



Photograph 7- 12. Hershey Chute Rock Revetment, River Mile 461.5, circa 2000

Photograph 7- 13. Hershey Chute Rock Revetment, River Mile 461.5, circa 2012

12. Hard Points in Side Channels. Hard points (figure 7-15) are a concentration of stone or other material placed at regular intervals along the eroding bank. Hard points can be trenched in, keyed in, or just dumped on the existing bank. The hard points work by resisting the acting forces associated with bank failure.

Figure 7-15. Hard Points

a. Lessons Learned. Success depends on the ability of the stone to launch into the scour hole formed from the hard point. Some bank scalloping can be expected between hard points. Little or no bank grading or reshaping is needed. Hard points are a good choice for straight reaches and large radius bends; and not recommended in areas suffering impinging flow, or for high degree-of-curvature, small radius bends. Hard points include several good environmental features including: semi-protected slack water areas between hard points; scour hole at stream end of hard point; vertical scalloped banks between hard points; and natural the vegetation on the banks and the crowns of hard points provides cover and a source of carbon loading to the system.

b. Case Study

Duck Island Side Channel. Hard points were constructed in the Duck Island side channel to protect the bankline of a large radius bend. Hard points were built in the Owl Creek reach not to protect the bankline but to create a scour pattern to separate a large sandbar from the bankline (photographs 7-14 and 7-15).

Photograph 7-13. Duck Island Hard Points

Photograph 7-14. Owl Creek Hard Points

13. Vanes. Rock vanes are in-stream structures constructed for the purpose of reducing shear stress on streambanks. Rock vanes consist of both footer rocks, placed below the invert of the proposed channel, as well as vane rocks. Rock vanes should be constructed of angular, flat or cubed rock. When possible, consideration should be given to obtaining rock that is similar in color and texture to the native stone in the project area.

Rock should be of hard enough to resist weathering and free of cracks and other blemishes. Porous rock such as some limestones, soft rock such as shale, concrete, or other “debris” should not be used for vanes. Figure 7-16 shows typical vane details.

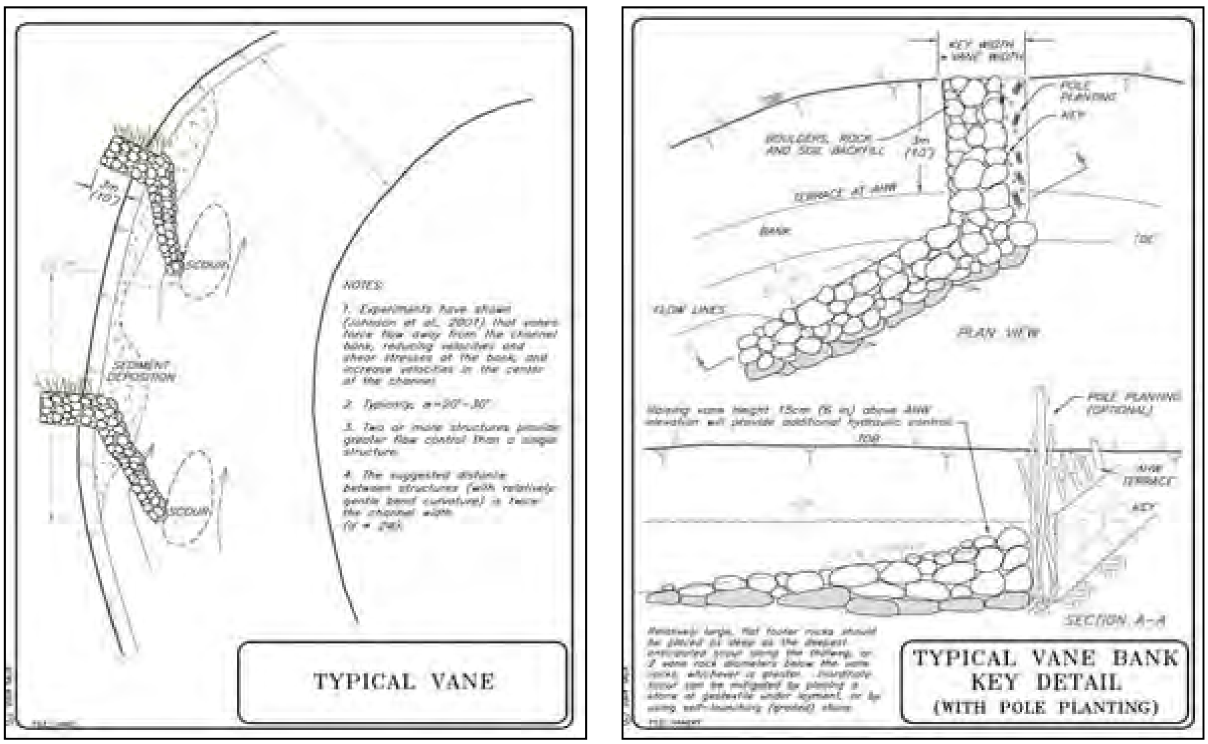


Figure 7-16. Typical Vane Details

Iowa Vanes are small, double-curved, patented structures for sediment management in rivers. They are designed to protect stream banks from erosion, maintain navigation depth and flood-flow capacity in rivers, and control sediment at diversions and water intakes. Figures 7-17 and 7-18 show flow around an Iowa vane.

Iowa vanes are small, submerged flow-training structures or foils designed to modify the near-bed flow pattern and redistribute flow and sediment transport within the channel cross section. The vanes function by generating secondary circulation in the flow. The circulation alters magnitude and direction of the bed shear stresses and causes a change in the distribution of velocity, depth, and sediment transport in the area affected by the vanes. As a result, the riverbed aggrades in one portion of the channel cross section and degrades in another.

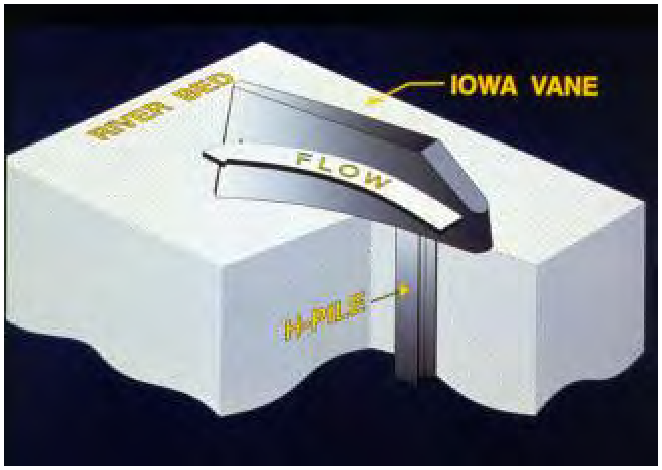


Figure 7-17. Iowa Vane

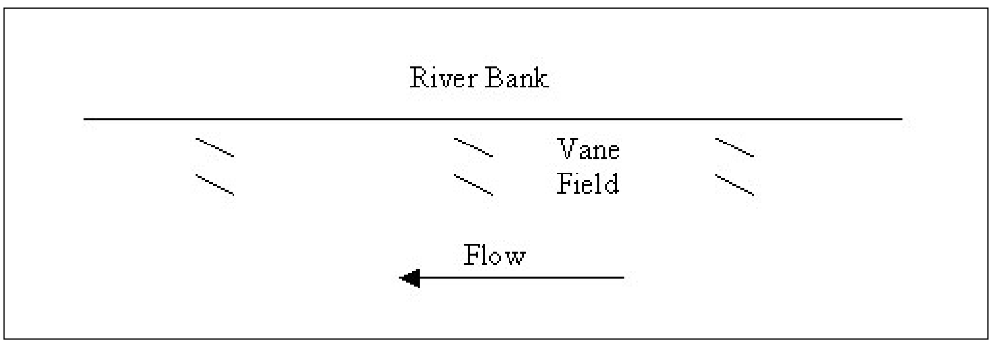


Figure 7-18. Flow Field

Russian engineers Potapov and Pyshkin (Rosgen, 1996) originally proposed the use of vanes or panels for flow training. However, it is only recently efforts have been made to optimize vane design and document performance. The first known attempts to develop a theoretical design basis were by Odgaard and Kennedy (1983) and Odgaard and Spoljaric (1986). Odgaard and Kennedy's efforts were aimed at designing a system of vanes to stop or reduce bank erosion in river curves. In such an application, the vanes are laid out so the vane-generated secondary current eliminates the centrifugal induced secondary current, which is the root cause of bank undermining. The centrifugal induced secondary current in river bends results from the difference in centrifugal acceleration along a vertical line in the flow because of the non-uniform vertical profile of the velocity. The secondary current forces high-velocity surface current outward and low-velocity near-bed current inward.

The increase in velocity at the outer bank increases the erosive attack on the bank, causing it to fail. By directing the near-bed current toward the outer bank, the submerged vanes counter the centrifugal induced secondary current and, thereby, inhibit bank erosion. The vanes stabilize the toe of the bank. The vanes can be laid out to make the water and sediment move through a river curve as if it were straight (table 7-2).

Table 7-2. Typical Vane Dimensions

Vane height, H	1-3 m (0.2-0.3 times design flow depth)
Vane thickness	0.05-0.20 m
Vane length, L	3H
Lateral spacing	3H
Longitudinal spacing	30H
Distance to bank or intake	3H
Angle of attack	20 degrees
Vane material	Wood, sheet pile, concrete

a. Lessons Learned. The upstream angle of the structure is critical. For the structure to work properly the upstream angle needs to be into the bank in the downstream direction. The resultant flow will be at a 90 ° angle perpendicular to the vane.

b. Case Studies

West Fork Cedar River, IA. Photograph 7-15 shows the vane-induced shift of the main channel. The installation consists of 12 vanes installed along the right-bank upstream of the bridge. Each vane consists of vertical sheet piles driven into the streambed and aligned at 20 degrees with the 1984 mean flow direction. Each sheet piling is 3.7 m long, and its top elevation is 0.6 m above the streambed.

Photograph 7-15. Aerial Photograph of West Fork Cedar River (Iowa) Bridge Crossing (Left) Prior to Vane Installation in 1984, and (Right) in 1989, Five Years after Vane Installation

Kosi River, Nepal. Photograph 7-16 shows vanes being installed outside new water intake on Kosi River, Nepal. The vane system will prevent sediment from being entrained into the intake (left). Each vane is 6 m long and 1.5 m-tall (with 0.8 m of vane below average bed level). Longitudinal spacing varies between 30 m and 40 m; lateral spacing is 5 m.

Photograph 7-16. Vane System - Kosi River, Nepal

14. Cross Vane and Double Cross Vane. This structure was designed to off-set the adverse effects of straight weirs, and check dams, which create backwater and flat slopes. It was also designed to avoid the problems of the downstream pointing weirs which create twin parallel bars and a scour hole which de-stabilizes the structure. The objectives of this structure are to: (1) create instream cover/holding water; (2) take excess shear stress from the "near bank" region and direct it to the center of the stream to maintain later stability; (3) increase stream depth by decreasing width/depth ration; (4) increase sediment transport capacity; (5) provide a natural sorting of gravel (where naturally available) on the up-welling portion on the downstream side of the structure for spawning fish, and; (6) create grade control to prevent down cutting.

Rock should be hard enough to resist weathering and free of cracks and other blemishes. Porous rock such as some limestones and soft rock as shale should not be used. In some cases, native rock present on the site may be authorized for use by the contracting officer. In no instance will concrete or other "debris" be allowed. All rock under this specification shall meet the conditions of material specification MS-01 Rock. Typical details are shown in figure 7-19.

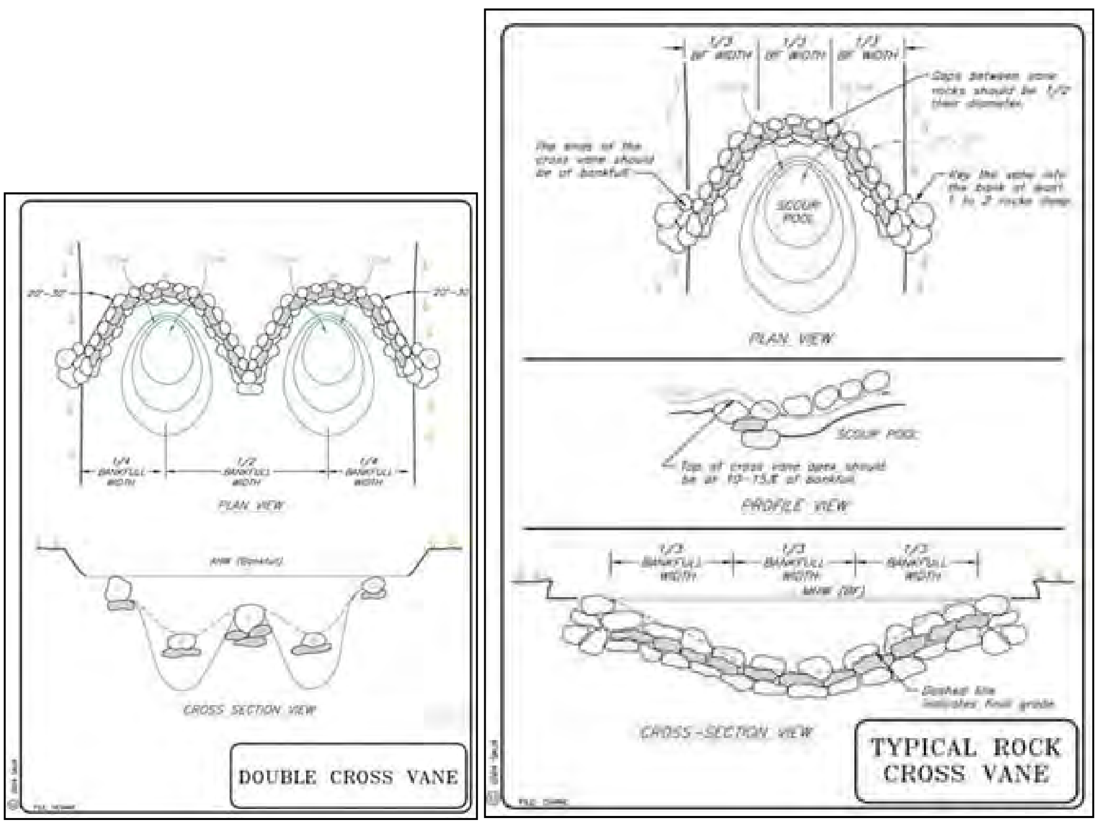


Figure 7-19. Typical Cross Vane Details

a. Lessons Learned. When the rock is placed, make sure the footer rocks are working in compression with flow or the integrity of the structure will be compromised. When building the structure, alternate the size of the stone, allowing voids in the structure to allow for fish passage. If used as a grade control structure and the head cut is relatively high, use a series of structures instead of one large structure to allow for fish passage.

b. Case Studies. None listed.

15. J-Hook. J-Hook Rock Vanes (figure 7-20) are structures designed to re-direct velocity distribution and high velocity gradient in the near-bank region, stabilize streambanks, dissipate energy in deep, wide and long pools are created below the structure, and create holding cover for fish and spawning habitat in the tail-out of the structure. The basic function of the structure utilizes the principle water will flow over immoveable objects at right angles (90° angles). The device is constructed of large stone tied into the stream bank. The stone is trenched into two rows at an upstream angle of 20° to 30° at a distance of 1/3 stream width. The stone is then formed into a hook shape to cover a distance of 1/3 stream width. The downstream row of rock is trenched into the stream bottom so the top of the rock is approximately level with the stream bottom.

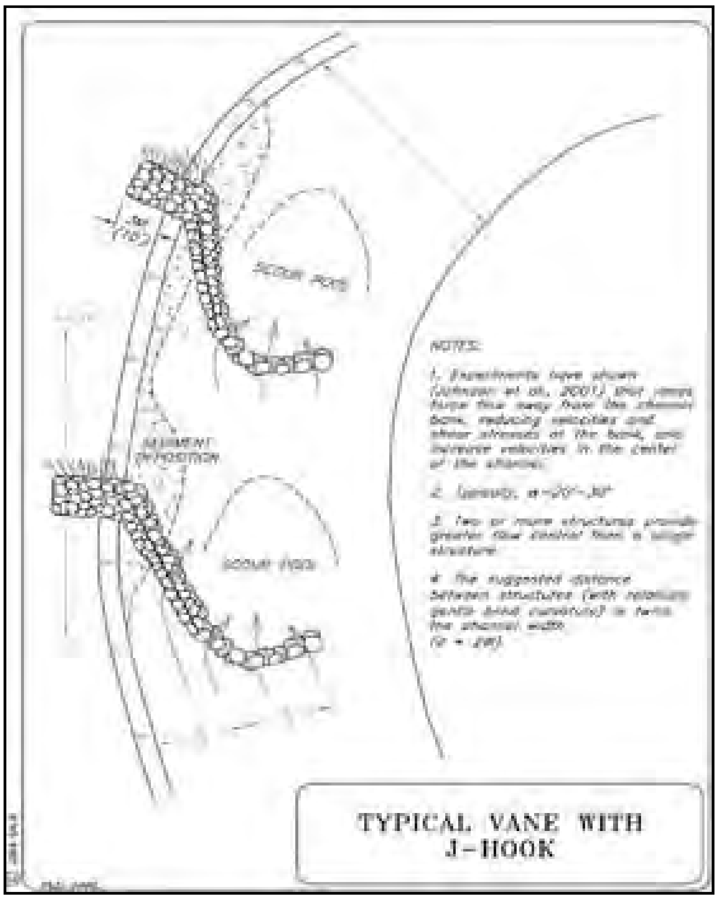


Figure 7-20. Vane With J-Hook

The second row of rock is then placed just upstream of that row of rock slightly overlapping it so the water flows over the top of the upstream line of rock slightly overlapping it. As the water flows over the top of the upstream line of rock it will flow onto the downstream line of rock. This creates a stable surface on which the energy of the stream can be dissipated without completely scouring the stream bottom. As the stream dissipates its energy, it will scour the stream bottom slightly, creating a small scour pool immediately downstream of the device serving as a source of aquatic habitat.

a. Lessons Learned. When the rock is placed, make sure the footer rocks are working in compression with flow or the integrity of the structure will be compromised. When building the structure, alternate the size of the stone, allowing voids in the structure to allow for fish passage (McCullah, 2004).

b. Case Study

Marion Creek, AK used J-Hook Structure (photograph 7-17)

Photograph 7-17. Marion Creek, AK

16. Multiple Roundpoint Structures. Multiple Roundpoint Structures (MRS) (figure 7-21) are used to create bathymetric and flow diversity in streams and rivers. The MRS induce scouring off the tips of the structures and create depositional areas with the increased roughness generated by the structures. Flow diversity is created with high velocities off the tips of the structures and slack water areas downstream of the structures. The MRS can also act as a primitive bank stabilization technique by creating depositional zones near the banks of the structures (USACE, 2000).

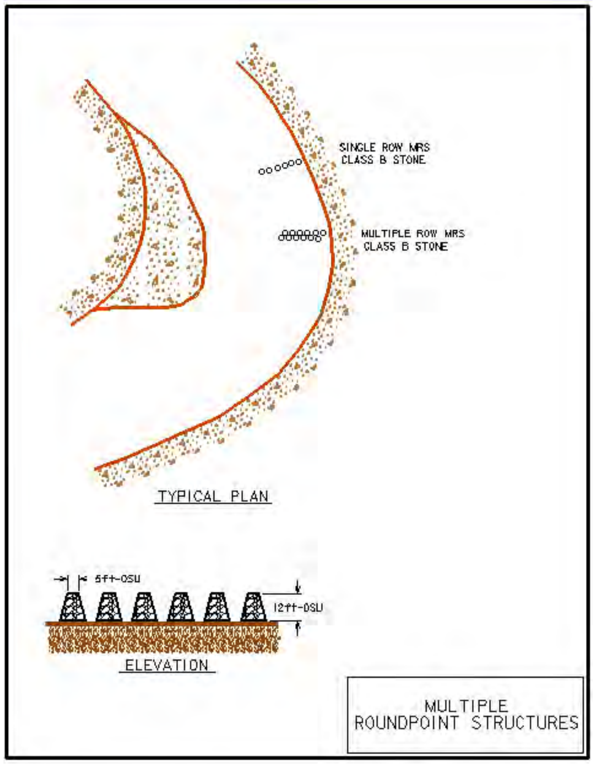


Figure 7-21. Multiple Roundpoint Structures

The structures are generally built to 2/3 bankfull and the grade of stone needed is channel dependent. The spacing of the MRS is dependent of the height of the structure and natural angle of repose the rock used. A rule of thumb with the spacing between the structures is space them no less than 2/3 of the height.

Multiple roundpoint structures can be designed as a single row or in multiple rows. Preliminary data shows the more rows incorporated generate increased bathymetric changes.

a. Lessons Learned. Multiple Roundpoint Structures are not recommended as a bank stabilization technique but can be incorporated with other forms of bank stabilization such as revetment or Longitudinal Peak Stone Toe. The data collected suggest MRS are providing useful and valuable habitat for a variety of riverine fishes. Collection of blue suckers may indicate these structures are providing a unique habitat type, once more common in the river.

b. Case Studies. Photograph 7-18 shows an MRS on the Mississippi River.

Photograph 7-18. US Army Corps of Engineers, St. Louis District Riprap Landing Multiple Roundpoint Structures, Middle Mississippi River Mile 265.7.

17. Environmental Dredging. Side channels of rivers are important spawning and rearing habitat for fish. Their slower waters offer less scouring of eggs during flooding and offer better tree cover and logs in the water to hide fry after they emerge from the gravel. In a naturally functioning watershed, side channels may become isolated from the river and slowly fill in with sediment and vegetation. This eutrophication process happens much faster in shallow, narrow side channels than in deep wide lakes. Side channels can go from productive fish habitat to dry land in less than 50 years (USACE, 1995). Reopening theses side channels by the process of dredging is termed "environmental dredging". Dredging in the St. Louis district is accomplished by using hydraulic pipeline dredges (photograph 7-19).

Photograph 7-19. Dredge Using Hydraulic Pipeline

A hydraulic dredge mixes large quantities of water with the excavated material (almost always sand in the St. Louis District) to create a slurry which is then pumped out of the navigable channel. The two types of hydraulic pipeline dredges used by St. Louis are the *Dustpan* and the *Cutterhead.* The Dustpan Dredge was specifically designed by USACE for work on the Mississippi River. The Dustpan is very efficient in excavating sand material from the river bottom. Water jets at the end of the suction head agitate the sand into a slurry which is then pumped up into the dredge. The discharge is pipelined a short distance, typically around 800 feet, outside of the navigable channel. A Cutterhead Dredge has an active rotating auger surrounding the suction line. The material is pumped up to the dredge and discharged through a pipeline up to 3,000 feet away.

a. Lessons Learned. Dredging is coordinated with other government agencies so the Corps operations are conducted in an environmentally sensitive manner. It is a continual process and new techniques are continually being developed to reduce the environmental impact associated with channel dredging.

b. Case Study

US Army Corps of Engineers, Rock Island District Dredge 5,000 feet of O'Dell Chute, Pool 21, Upper Mississippi River RM 332.5 – 340.2,

18. Longitudinal Peak Stone Toe Protection (LPSTP). A continuous stone dike comprised of well sorted, self launching stone, placed at, or slightly streamward of, the toe of the eroding bank. The cross-section is triangular. The LPSTP does not necessarily follow the toe exactly, but can be placed to form a "smoothed" alignment through the bend. The amount of stone used is based on tons per linear foot. In determining the tonnage you first must calculate the depth of scouring resulting in the stone placement. 2 tons/linear ft are the most common tonnage, resulting in approximately 5 feet of toe protection.

The design consideration for LPSTP keys indicates they must be keyed into the bank at both the upstream and downstream ends and at regular intervals along the entire length. Typically the keys are spaced at 50 to 100ft intervals up to 1 to 2 channel widths on larger waterways. Keys at the upstream and the downstream ends of the LPSTP should not be at a 90 ° angle to the structure, but at 20 to 30° to flow. Keys should go far enough into the river bank so river migration will not flank the key and the LPSTP (figure 7-22 and photograph 7-20).

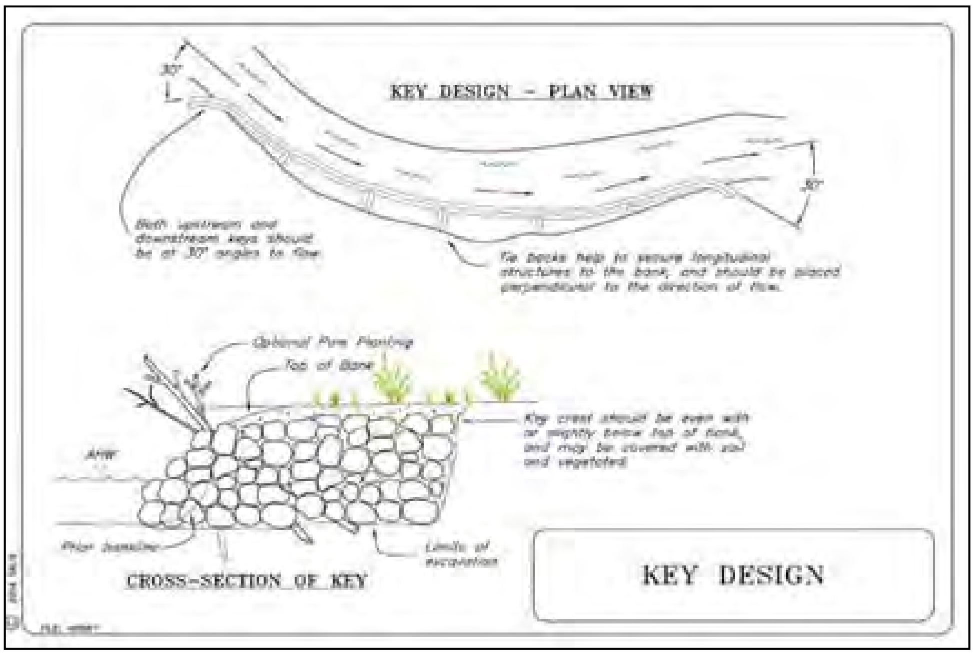


Figure 7-22. Longitudinal Peak Stone Toe Protection

Photograph 7-20. Longitudinal Peak Stone Toe Protection

a. Lessons Learned. The success depends on the ability of the stone to launch into the scour hole. River bank grading is not necessary. The weight of stone (loading of toe) might resist some shallow-fault geotechnical bank failures. The LPSTP captures alluvium and upslope failed material on bank side of structure. Works well where outer bank alignment makes abrupt changes, where the bank must be built back into the stream (realignment of channel, or construction of a backfilled vegetative bench or terrace for habitat improvement and/or velocity attenuation), where a minimal continuous bank protection is needed, or where a "false bankline" is needed. Works well in combination with other methods (bendway weirs, spur dikes, bioengineering, joint planting, live siltation, and live staking).

b. Case Studies. None listed.

19. Bioengineering and Biotechnical Engineering. Vegetation has been used increasingly over the past few decades to control streambank erosion or as a bank stabilizer. It has been used primarily in stream restoration and rehabilitation projects and can be applied independently or in combination with structural countermeasures. There are several synonymous terms describing the field of vegetative streambank stabilization and countermeasures. Terms for the use of 'soft' revetments (consisting solely of living plant materials or plant products) include bioengineering, soil bioengineering, ground bioengineering, and ecological bioengineering. Terms describing the techniques combining the use of vegetation with structural (hard) elements include biotechnical engineering, biotechnical slope protection, bioengineered slope stabilization, and biotechnical revetment. The terms soil bioengineering and biotechnical engineering are most commonly used to describe stream bank erosion countermeasures and bank stabilization methods that incorporate vegetation.

The effective application of soil bioengineering and biotechnical engineering techniques requires expertise in channel and watershed processes, biology, and streambank stabilization techniques. Due to a lack of technical training and experience, there is a reluctance to resort to soil bioengineering and biotechnical engineering techniques and stability methods. In addition, bank stabilization systems using vegetation have not been standardized for general application under particular flow conditions.

There is a lack of knowledge about the properties of the materials being used in relation to force and stress generated by flowing water and there are difficulties in obtaining consistent performance from countermeasures that rely on living materials. Photograph 7-21 shows an example of bioengineering.

Photograph 7-21. Rock Vanes with Bioengineering, Urban Setting, Charlotte, NC (photograph: Andrew Burg)

Following are specific ways vegetation can protect stream banks as part of a biotechnical engineering approach.

- The root system binds soil particles together and increases the overall stability and shear strength of the bank.
- The exposed vegetation increases surface roughness and reduces local flow velocities close to the bank, which reduces the transport capacity and shear stress near the bank, thereby inducing sediment deposition.
- Vegetation dissipates the kinetic energy of falling raindrops, and depletes soil water by uptake and transpiration.
- Vegetation reduces surface runoff through increased retention of water on the surface and increases groundwater recharge.
- Vegetation deflects high-velocity flow away from the bank and acts as a buffer against the abrasive effect of transported material.
- Vegetation improves the conditions for fisheries and wildlife and helps improve water quality.

In addition, biotechnical engineering is often less expensive than most methods that are entirely structural and it is often less expensive to construct and maintain when considered over the long-term.

The critical threats to the successful performance of biotechnical engineering projects are improper site assessment, design or installation, and lack of monitoring and maintenance (especially following floods and during droughts). Some of the specific limitations to the use of vegetation for streambank erosion control include:

- lack of design criteria and knowledge about properties of vegetative materials;
- lack of long-term quantitative monitoring and performance assessment;
- difficulty in obtaining consistent performance from countermeasures relying on live materials;
- possible failure to grow and susceptibility to drought conditions;
- depredation by wildlife or livestock; and
- requiring significant maintenance.

More importantly, the type of plants surviving at various submersions during the normal cycle of low, medium, and high stream flows is critical to the design, implementation, and success of biotechnical engineering techniques. A bioengineering technique is shown in photograph 7-22.

Photograph 7-22. Bioengineering Using Willow

a. Design Considerations for Biotechnical Engineering. In an unstable watershed, careful study should be made of the causes of instability before biotechnical engineering is contemplated (FHA, 2001, Chapter 4, *Reconnaissance Classification, and Response*). Since bank erosion is tied to channel stability, a stable channel bed must be achieved before the banks are addressed. Scour and erosion of the bank toe produce the dominant failure modes (FHA, 2001) consequently, most biotechnical engineering projects documented in the literature contain some form of structural (hard) toe stabilization, such as rock riprap (figure 7-23), rock gabions, cribs, cable anchored logs, or logs with root wads anchored by boulders (figure 7-24).

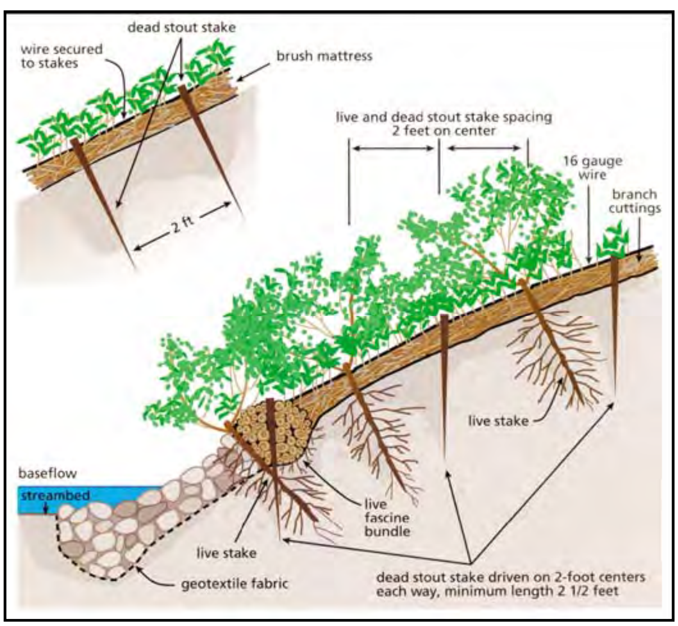


Figure 7-23. Details of Brush Mattress Technique With Stone Toe Protection

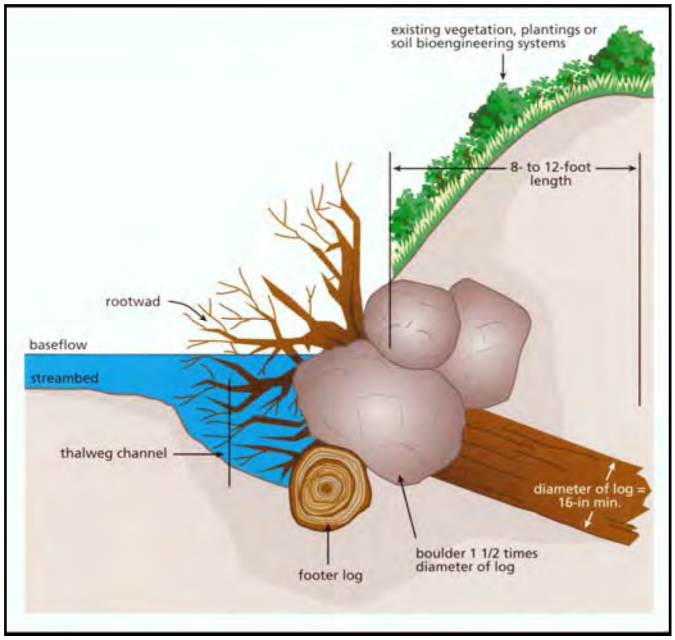


Figure 7-24. Details of Root Wad and Boulder Revetment Technique

Toe protection should be keyed into the channel bed sufficiently deep to withstand significant scour and the biotechnically engineered revetment should be keyed into the bank at both the upstream and downstream ends (called refusals) to prevent flanking. Deflectors such as fences, dikes, and pilings may also be utilized to deflect flow away from the bankline.

Other factors that need to be considered when selecting a design option include climate and hydrology, soils, cross-sectional dimensions (is there sufficient room for the countermeasure), flow depth, flow velocity (both magnitude and direction), and slope of the bankline being protected. Most methods of biotechnical engineering will require some amount of bank regrading. Because structure design is based on flood velocities and depths, one or more design flows will need to be analyzed. Of particular interest is the bankfull or overtopping event, since this event generates the greatest velocities and tractive forces. Local (at or near the project site) flow velocities should be used for the design, especially along the outside of bends. The erosion protection should extend far enough downstream, particularly on the outer banks of bends. The highest velocities generally occur at the downstream arc of a bend and on the outer bank of the exit reach immediately downstream. As noted, the countermeasures should be tied into the bank at both ends to prevent flanking.

b. Streambank Zones. As indicated by U.S. Army Engineer Waterways Experiment Station (WES), (50) plants should be positioned in various elevational zones of the bank based on their ability to tolerate certain frequencies and durations of flooding, and their attributes of dissipating current- and wave energies (1998). The stream bank is generally broken into three or four zones to facilitate prescription of the biotechnical erosion control treatment. Because of daily and seasonal variations in flow, the zones are not precise and distinct. The zones are based on their bank position and are defined as the toe, splash, bank and overbank zones (figure 7-25).

The toe zone is the area between the bed and the average normal stage. This zone is often under water more than six months of the year. It is a zone of high stress and is susceptible to undercutting and scour resulting in bank failure.

The splash zone is located between the normal high-water and normal low-water stages and is inundated throughout much of the year (at least six months). Water depths fluctuate daily, seasonally, and by location within the zone. This zone is also an area of high stress, being exposed frequently to wave-wash, erosive currents, ice and debris movement, wet-dry cycles, and freeze-thaw cycles.

Because the toe and splash zones are the zones of highest stress, these zones are treated as one zone with a structural revetment, such as rock, stone, logs, cribs, gabions, or some other 'hard' treatment. Within the splash zone, flood-resistant herbaceous emergent aquatic plants like reeds, rushes, and sedges may be planted in the structural element of the bank protection.

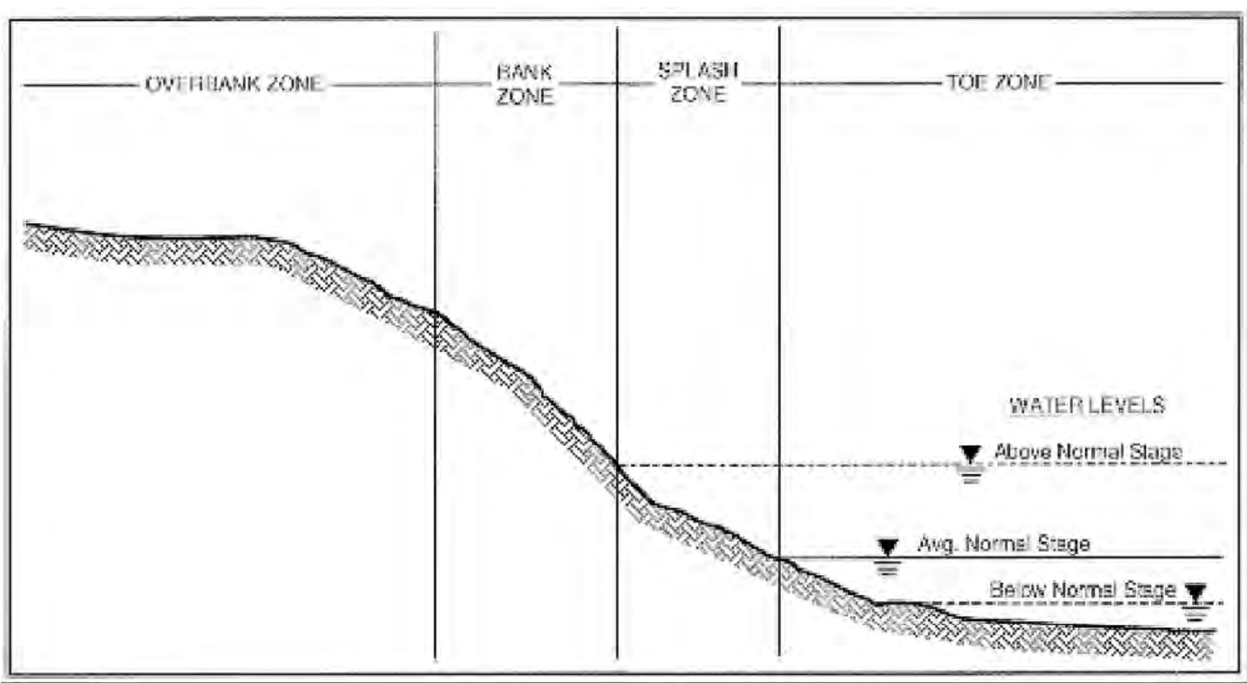


Figure 7-25. Bank Zones Defined for Slope Protection

The bank zone is usually located above the normal high-water level, but is exposed periodically to wave-wash, erosive flows, ice and debris movement, and traffic by animals or man. This zone is inundated for at least a 60-day duration once every two to three years and is influenced by a shallow water table. Herbaceous (i.e., grasses, clovers, some sedges, and other herbs) and woody plants (i.e., willows, alder, and dogwood) that are flood tolerant and able to withstand partial to complete submergence for up to several weeks are used in this zone. Whitlow and Harris (1979) provide a listing of very flood-tolerant woody species and a few herbaceous species by geographic area within the United States.

The overbank zone includes the top bank area and the area inland from the bank zone, and is usually not subjected to erosive forces except during occasional flooding. Vegetation in this zone is extremely important for intercepting overbank floodwater, binding the soil in the upper bank together through its root system, helping reduce super-saturation of the bank, and decreasing the weight of unstable banks through evapotranspiration processes. This zone can contain grasses, herbs, shrubs, and trees that are less flood-tolerant than those in the bank zone. The rooting depth of trees can be an extremely important part of bank stability. Besides erosion control, wildlife habitat diversity, aesthetics, and access for project construction and long-term maintenance are important considerations in this zone.

c. Biotechnical Engineering Treatments. Descriptions and guidelines for biotechnical engineering treatments or combinations of treatments, and plant species used in the treatments are described in detail by WES,(1998) Bentrup and Hoag,(1998) and Schiechtl and Stern (1997). The following is a brief summary of some of the major types of biotechnical engineering treatments that can be used separately or in some combination.

i. Toe Zone. Structural revetments such as riprap, gabions, cribs, logs, or rootwads in a biotechnical engineering application are used at the toe in the zone below normal water levels and up to where normal water levels occur. There are no definitive guidelines for how far up the bank to extend the structural revetment. Instead, it is common practice to extend the revetment from below the predicted contraction and local scour depth up to at least where the water flows the majority of the year. Vegetative treatments are placed above or behind this structural toe protection.

ii. Splash Zone. Several treatments may be used individually or in combination with other treatments in the splash zone above or behind the structural toe protection. These include coir rolls and mats, brush mattresses, wattles or fascines, brush layering, vegetative geogrid, dormant posts, dormant cuttings, and root pads.

Coir is a biodegradable geotextile fabric made of woven fibers of coconut husks and is formed into either rolls (coir roll) or mats (coir fiber mats). Coir rolls are often placed above the structural toe protection parallel to the bank with wetland vegetation planted or grown in the roll. Coir fiber mats are made in various thicknesses and are often pre-vegetated at a nursery with emergent aquatic plants or sometimes sprigged on-site with emergent aquatic plants harvested from local sources.

Brush mattresses, sometimes called brush matting or brush barriers, are a combination of a thick layer of long, interlaced live willow switches or branches and wattling. Wattling, also known as fascine, is a cigar-shaped bundle of live, shrubby material made from species that root rapidly from the stem. The branches in the mattress are placed perpendicular to the bank with their basal ends inserted into a trench at the bottom of the slope in the splash zone, just above the structural toe protection. The fascines are laid over the basal ends of the brush mattress in the ditch and staked. The mattress and fascines are kept in place by either woven wire or tie wire that is held in place by wedge-shaped construction stakes. Both are covered with soil and tamped.

Brush layering, also called branch layering or branch packing, is used in the splash zone as well as in the bank zone. This treatment consists of live branches or brush that quickly sprout, such as willow or dogwood species, placed in trenches dug into the slope, on contour, with their basal ends pointed inward and the tips extending beyond the fill face. Branches should be arranged in a criss-cross fashion and covered with firmly compacted soil. This treatment can also be used in combination with live fascines and live pegs.

Vegetative geogrid is also used in the splash zone and can extend farther up into the bank zone and possibly the overbank zone. This system is also referred to as "fabric encapsulated soil" and consists of successive walls of several lifts of fabric reinforcement with intervening long, live willow whips. The fabric consists of two layers of coir fabric which provide both structural strength and resistance to piping of fine sediments.

Dormant post treatment consists of placing dormant, but living stems of woody species that sprout stems and roots from the stem, such as willow or cottonwood, in the splash zone and the lower part of the bank zone. Post holes are formed in the bank so that the end of the post is below the maximum predicted scour depth. Posts can also be planted in riprap revetments.

Willows can be harvested at project construction inception so material can be soaked for as long as possible to increase chances of survival during summertime planting Research shows willow protected from the sun and soaked for 10 days will have twice as many plants survive, 100% initial flush, and 32 fold {2600%} more root biomass.

Dormant cuttings, also known as live stakes, consist of inserting and tamping live, single stem, rootable cuttings into the ground or sometimes geotextile substrates. In the splash zone of high velocity streams, this method is used in combination with other treatments, such as brush mattresses and root wads. Dormant cuttings can be used as live stakes in the brush mattress and fascines in the place of or in combination with the wedge-shaped construction stakes (figure 7-20).

Root pads are clumps of shrubbery composed of woody species that are often placed in the splash zone between root wads (figure 7-22). Root pads can also be used in the bank and overbank zones, but should be secured with stakes on slopes greater than 1V:6H.

iii. Bank Zone. This zone can be stabilized with the treatments previously described as well as with sod, mulching, or a combination of treatments. Sodding of flood-tolerant grasses can be used to provide rapid bank stabilization where only mild currents and wave action are expected. The sod is held in place with some sort of wire mesh, geotextile mesh such as a coir fabric, or stakes. Coir mats may extend into this zone. Shrub-like woody transplants or rooted cuttings are also effective in this zone and are often placed in combination with tied-down and staked mulch that is used to temporarily reduce surface erosion. For areas where severe erosion or high currents are expected, methods such as brush mattress should be carried into the bank zone.

Contour wattling consists of fascines, often used independent of the brush mattress, placed along contours, and buried across the slope, parallel or nearly parallel to the stream course. The bundles can be living or constructed from wood and are staked to the bank. Contour wattles are often installed in combination with a coir fiber blanket. Overseeding and straw mulch will help prevent the development of rills or gullies.

Brush layering with some modifications can be used in the bank zone. Geotextile fabrics should be used between the brush layers and keyed into each branch layer trench to prevent unraveling of the bank between the layers.

iv. Overbank Zone. Bioengineered treatments are generally not used in this zone except to control gullying or where slopes are greater than 1V:3H. In these cases, brush layering or contour wattling is employed across the gully or on the contour of the slope.

Deep-rooting plants, such as larger flood-tolerant trees, are required in this zone in order to hold the bank together. Care should be taken in the placement of trees that may grow to be fairly large since their shade can kill out vegetation in the splash and bank zones. Trees planted in the overbank zone are planted either as container-grown or bare-root plants.

Depending on their shade tolerance, grasses, herbs, and shrubs can be planted between the trees. Hydroseeding and hydromulching are useful and effective means of direct seeding in the overbank zone.

d. Summary . Biotechnical engineering is a useful and cost-effective tool in controlling bank erosion or providing bank stability at highway bridges, while increasing the aesthetics and habitat diversity of the site. However, where failure of the countermeasure could lead to failure of the bridge or highway structure, the only acceptable solution may be traditional, "hard" engineering approaches. Biotechnical engineering needs to be applied in a prudent manner, in conjunction with channel planform and bed stability-analysis, and rigorous engineering design. Designs must account for a multitude of factors associated with the geotechnical characteristics of the site, the local and watershed geomorphology, local soils, plant biology, hydrology, and site hydraulics. Finally, programs for monitoring and maintenance, which are essential to the success and effectiveness of any biotechnical engineering project, must be included in the project and strictly adhered to.

e. Lessons Learned. Stabilization of eroding stream banks using vegetative countermeasures has proven effective in many documented cases in Europe and the United States. Most hydraulic engineers in Europe would not recommend the reliance on bioengineering countermeasures as the only countermeasure technique when there is a risk of damage to property or a structure, or where there is potential for loss of life if the countermeasure fails. Soil bioengineering is not suitable where flow velocities exceed the strength of the bank material or where pore water pressure causes failures in the lower bank. In contrast, biotechnical engineering is particularly suitable where some sort of engineered structural solution is required, but the risk associated with using just vegetation is considered too high. Nonetheless, this group of countermeasures is not as well accepted as the classical engineering approaches to bridge stability.

f. Case Studies. None Listed

20. Wood Pile Structures. Prior to the 1960s almost all of the structures placed in the Middle Mississippi River were of the woody pile type. Logs were basically driven in to the river bed to create roughness and formed into a river training structure. Due to the need for continual maintenance of these woody structures river training structures began to be constructed from stone during the 1960s. There is currently a big push to start bringing back the woody pile structures because of their benefit to the micro and macroinvertebrate species.

a. Lessons Learned. Woody pile structures should only be used in areas where bathymetric diversity is your goal. The structures should not be used where maintaining a navigation channel is your priority.

b. Case Study

Apalachicola River, FL. Photograph 7-23 shows a permeable wooden pile dike on the Apalachicola River, FL

Photograph 7-23. Permeable Wooden Pile Dike on the Apalachicola River, FL

21. Root wad Revetment. The objectives of this design are to: 1) protect the streambank from erosion; 2) provide in-stream and overhead cover for fish; 3) provide shade, detritus, terrestrial insect habitat; 4) look natural; and 5) provide diversity of habitats (figure 7-26 and photograph 7-24).

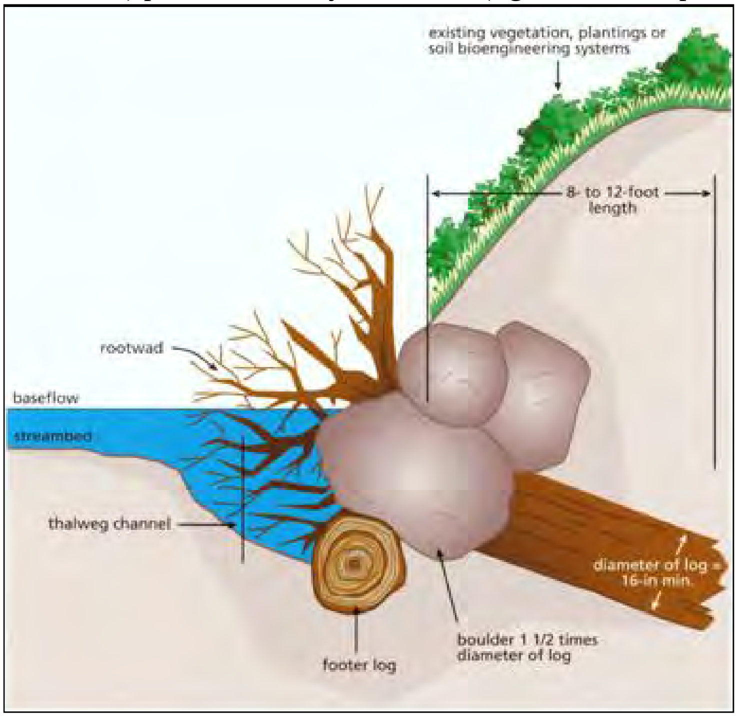


Figure 7-26. Root Wad Revetment

Photograph 7-24. Bankline Stabilization

a. Lessons Learned. The position relative to the water surface, frequent wetting and drying reduces life; continuously submerged wood lasts the longest.

b. Case Studies None Listed.

22. Woody Debris. Naturally occurring large woody debris (LWD) (i.e., >10 cm diameter and 2 m in length) is an important component of many lotic systems. It provides roughness, reducing velocities and overhead cover for fishes, substrate for aquatic invertebrates, and can be an important source of particulate organic matter adding to primary productivity of a river (Fischenich and Morrow, 2000).

Large woody debris dissipates flow energy, resulting in channel stability and improved fish migration. It also provides basking and perching sites for reptiles and birds. Positive effects of LWD are well-documented in high gradient streams, and recent studies show that the LWD is an important habitat component of low gradient streams with fine substrates.

Placing LWD into streams is an increasingly popular technique to improve fish and wildlife habitat. Large woody debris projects can be divided into two categories; improving the habitat by increasing the amount of LWD in the stream, and using LWD to alter flow in some way to improve aquatic habitat.

Some specific objectives that can be accomplished by using LWD are the following: Create pool habitat, generate scour, increase depths through shallow reaches, divert flows away from the bank to reduce erosion, armor stream banks to reduce erosion, promote bar formation through induced sediment deposition, and increase instream cover and refugia (figure 7-27).

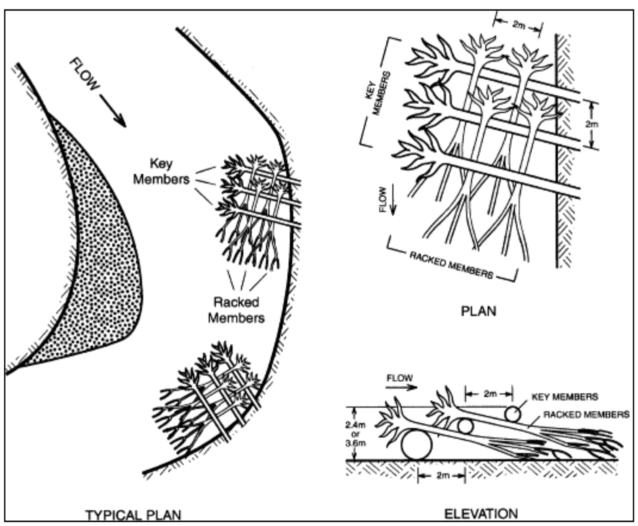


Figure 7-27. Woody Debris

Large woody debris commonly placed into the streams can be categorized as three types: whole trees, logs, and root wads. A whole tree is a tree cut off at the stump with all or most of the limbs attached, including terminal branches. Logs are sections of the bole with all sections removed. Rood wads consist of the root portion of the tree and the section of the bole.

a. Lessons Learned. The primary engineering concern is to ensure that anchoring is adequate to hold the structure in place during the most extreme flow conditions. Tree species: cypress, cedar, redwood, and oak last the longest. A dry and cool climate prolongs the life of the LWD. The position relative to the water surface, frequent wetting, and drying reduces life. Continuously submerged wood lasts the longest. Soil contact: microbial digestion in soils limits life, but burial in anaerobic soils prolongs life almost indefinitely.

b. Case Study

Large wood bundles have been placed in numerous scour holes in several side channels of the Middle Mississippi River (photograph 7-25)

Photograph 7-25. Wood Bundles

23. Boulder Clusters. Stones placed in a flowing channel with the top of the stone set at an elevation slightly lower than the typical base-flow water surface elevation. When sited correctly, the accelerated flow over the tops of the stones will change from sub critical to supercritical flow, and further downstream back to sub critical (usually with a weak hydraulic jump). Downstream of the stones, standing waves and a V-shaped wake will form. The stones also provide resting areas and in-channel refugee for fish during high energy, high-flow events. The hydraulic jump can also help to entrain air and aerate the stream (Derrick, 2005).

The crest elevations of the stones can also be placed at, or slightly above, the typical base-flow water surface elevation, which will split flow and result in a double eddy return flow pattern DS of the stone. However, these stones can now be used as perches for predators. Hydraulic Cover Stones are especially useful in sections of the stream with little in-channel structure, or vegetative cover, or undercut banks (figure 7-28).

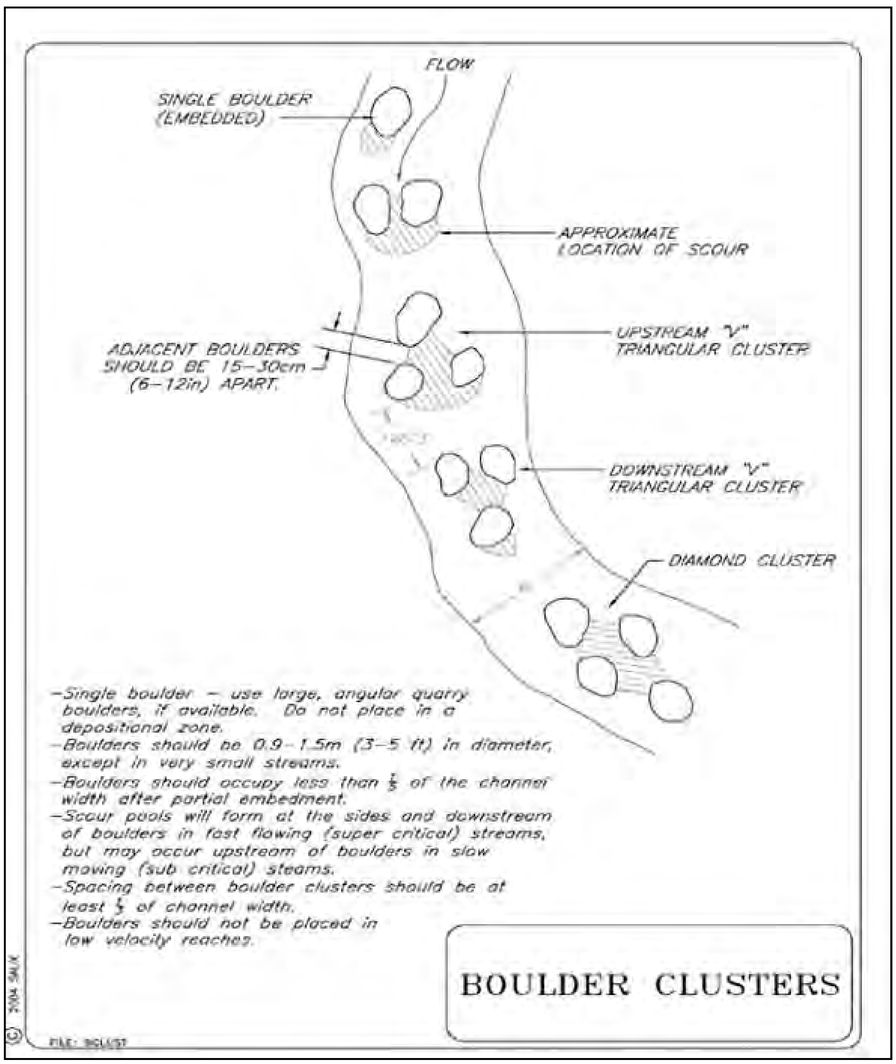


Figure 7-28. Boulder Clusters

a. Lessons Learned. Excessive scour can bury the boulder. The rock clusters block a large percentage of stream flow. It is possible for rock clusters redirect stream energy in unwanted direction. You can develop excessive deposition downstream of the cluster if not designed properly. If the rock cluster is too high, they can provide perches for predators and/or fishermen.

b. Case Study

Eighteen Mile Creek Salmon Stream Restoration, Newfane, NY (photograph 7-26)

Photograph 7-26. Boulder Clusters

24 Fish LUNKERS (Little Underwater Neighborhood Keepers Encompassing Rheotactic[2] Salmonids). A LUNKER structure, first developed and used in Wisconsin, is an engineered, overhanging-bank structure designed to provide habitat for aquatic fishes while providing bank stability. A LUNKER is typically 8 feet long, 1 to 2 feet tall, and 3 feet deep, constructed of hardwood (or concrete or plastic wood if numerous wet-dry cycles are anticipated), with an open front and ends. The toe of the outer bank of the stream is leveled, then the LUNKER is placed on the level bed and 0.5 inch x 7 feet long sections of rebar are driven through pre-drilled holes and into the stream substrate, anchoring the LUNKER to the stream bed. The area bankward of the LUNKER is filled with riprap, and either stones, or soil and a circular coir fiber roll are positioned on top of the LUNKER. Concrete-roofed LUNKERS can be used as fishing platforms in handicapped-accessible facilities (figure 7-29).

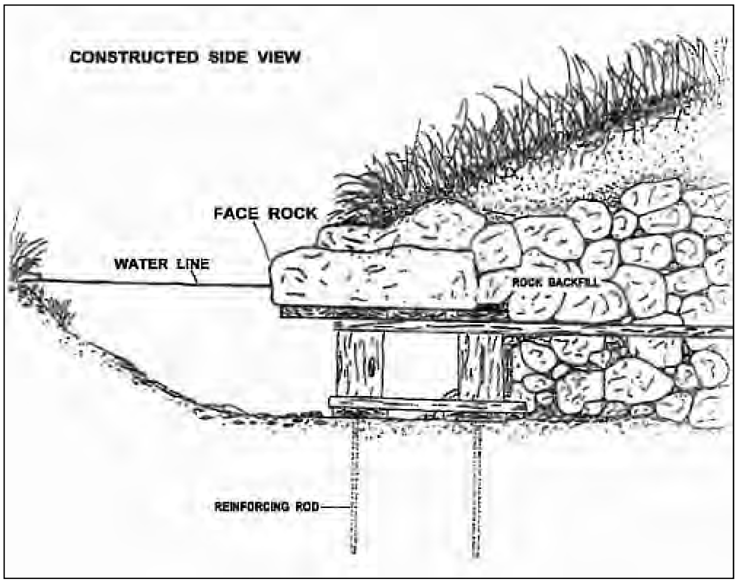


Figure 7-29. Fish LUNKER

a. Lessons Learned. Design deficiencies can occur if the LUNKER fills in with sediment, left high and dry, or exhibit scouring of the foundation materials resulting in collapse. Functioning LUNKERS require sufficient velocities to scour overhang area; reinforcing the foundation; and the low-flow water surface elevation to be on the header board.

[2]Rheotactic - fish that prefer to face into the current

b. Case Study

Eighteen Mile Creek Salmon Stream Restoration, Newfane, NY (photograph 7-27)

Photograph 7-27. Fish LUNKER

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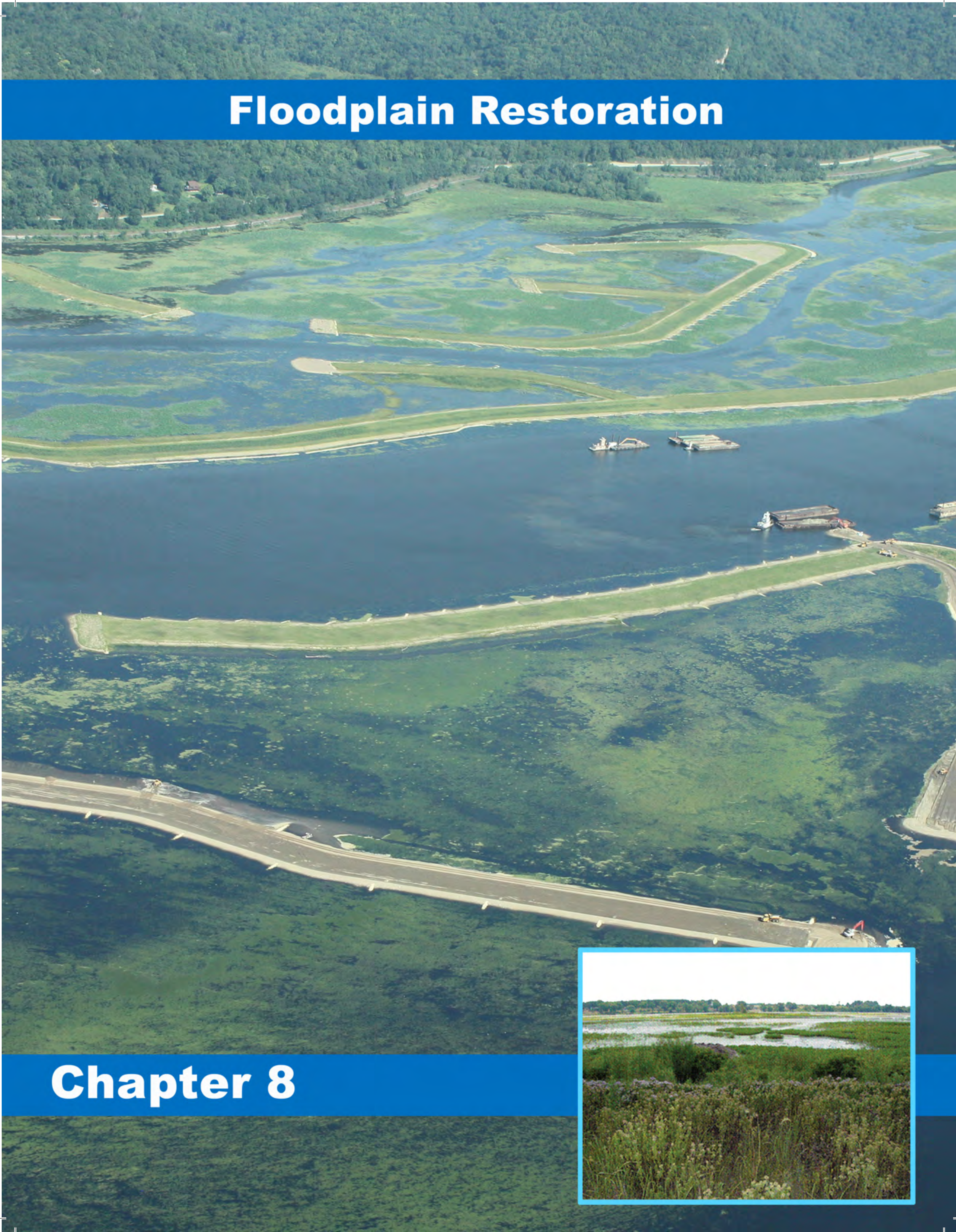
Floodplain Restoration



Chapter 8

UPPER MISSISSIPPI RIVER RESTORATION ENVIRONMENTAL MANAGEMENT PROGRAM ENVIRONMENTAL DESIGN HANDBOOK

CHAPTER 8

FLOODPLAIN RESTORATION

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CHAPTER 8

FLOODPLAIN RESTORATION

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CHAPTER 8

FLOODPLAIN RESTORATION

A. RESOURCE PROBLEM

Floodplain habitats are integral components of the large river ecosystems because of the seasonal flood pulse that inundates them and connects them to the river. River floodplain ecosystems support a wide variety of species, which are distributed along a flood frequency gradient from low elevation areas which are frequently inundated to areas of higher elevation infrequently inundated (figure 8-1).

Large floodplain rivers are dynamic, and disturbance is the key driver in maintaining the floodplain diversity. Flooding, droughts, sedimentation, channel migration, sediment re-suspension, fire, ice shear, tree wind-throw, log jams, and ecosystem engineers (e.g., beavers) are some of the natural disturbances that shape floodplains (USACE 2000). Man-made disturbances also have affected river habitats on the Upper Mississippi River System (UMRS). These include impoundment, water level regulation, dredging and dredge disposal, channel training structures, boat generated waves, levee construction, agriculture, nutrient enrichment, logging, urban development, and contaminants (USACE 2000). Navigation dams converted the free-flowing river to a series of shallow impoundments. Portions of the floodplain were permanently flooded by the dams and backwaters area increased significantly in the some northern reaches of the UMRS. Since impoundment, sedimentation of backwaters, island loss, and loss of secondary channels have greatly modified the river floodplain. Much of the southern reaches of the UMRS floodplain have been isolated by levees and the majority of the floodplain is in agricultural production. Additionally, forested reaches of the UMRS floodplain have experienced significant habitat degradation due to logging and subsequent conversion of land to agriculture. Deforestation and agricultural conversion throughout the basin has resulted in increased sediment delivery to the mainstem river.

Floodplain restoration in the northern reaches of the UMRS focuses primarily on constructing islands, dredging, and water level management. In the southern river reaches, floodplain restoration includes a mixture of water level management, connecting isolated backwater sloughs and lakes to the river, levee setbacks, and restoration of agricultural areas to aquatic, wetland, floodplain forest, bottomland hardwoods, and prairie habitats. The majority of floodplain restoration has occurred on public lands since privately-owned floodplain areas requires landowner cooperation or acquisition of real estate interested from willing sellers and donors.

Some floodplain restoration management actions include:

- Topographic Diversity (Ridge and swale; environmental dredging)
- Depressional Wetlands
- Reforestation
- Wetland Species Plantings (grasses, sedges, rushes, forbs)
- Levee Setbacks

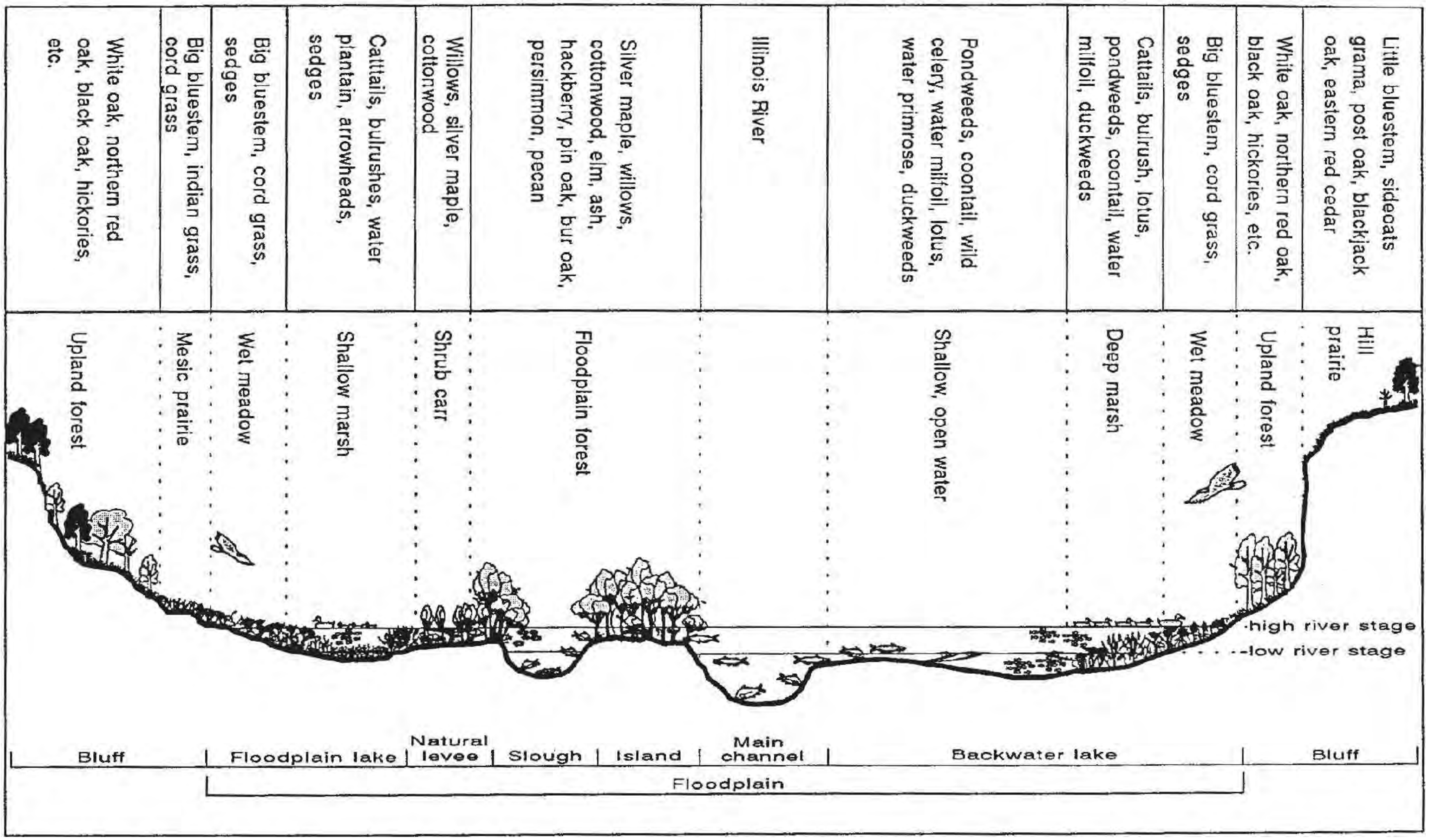


Figure 8-1. Cross-section of Habitat Types Typical of the Upper Mississippi River System (Sparks 1993)

B. MODELS

Conceptual models can be useful in visualizing how management actions link to project objectives as well as UMR system objectives. Figure 8-2 illustrates one example of how the management actions taken on the floodplain relate to system-, reach-, and project-specific biota objectives in terms of restoring UMR forest communities. In addition, management actions directly affecting hydrology and hydraulics and geomorphology can indirectly influence the biota objective.

The Ecosystem Functions Model (HEC-EFM) is a relatively new model designed to assist planning teams in determining ecosystem responses to changes in the flow regime of a river or connected wetland. The Rock Island District's Huron Island Habitat Rehabilitation and Enhancement Project (HREP) is currently using this model to design restoration features. HEC-EFM analysis involves 1) statistical analyses of relationships between hydrology and ecology; 2) hydraulic modeling; and 3) use of Geographic Information Systems to display results and other relevant spatial data. Through the analysis, planning teams should be able to visualize and define existing conditions, highlight potential restoration sites, and assess and rank alternatives according to predicted changes in different aspects of the ecosystem. Further model information and downloading instructions are available at: http://www.hec.usace.army.mil/software/hec-efm/.

C. TOPOGRAPHIC DIVERSITY

Topographic diversity refers to the ridge and swale pattern that forms in a natural floodplain. The process of sediment erosion and deposition form ridge and swale topography, which is an alternating sequence of narrow sandy ridges and low wetland swales that parallels the river. The ridges provide areas for flood intolerant tree species to become established. However, human modification (e.g., impoundment, leveling the floodplain for agriculture) to the floodplain has greatly reduced topographic diversity. Impoundment has elevated the water table leading to a loss of dry root zone and ultimately these flood intolerant tree species are eliminated for the forest community. Agriculture has leveled many areas changing hydrologic conditions, i.e., exposing sand lenses and draining areas ultimately altering that habitat that can be restored in these areas. Topographic diversity is essential for maintaining species diversity on floodplains, where relatively small differences in land elevation result in large differences in annual inundation and soil moisture regimes. These differences regulate plant distribution and abundance (Sparks 1992). Most topographic diversity restoration within the UMRS has occurred in conjunction with dredging. Material dredged from the main channel has been used to simulate ridges on the floodplain or as well as in island construction (See Chapter 9, *Island Design*, for more information). The newly elevated land area may then be planted with flood intolerant tree species (e.g., oaks and other hard mast tree).

1. Design Methodology

a. Potential Environmental Benefits. As proposed, this measure could be achieved through either the modification of existing geomorphic surfaces or through the creation of new ones. Increased topographic diversity in turn, would increase habitat diversity and benefit targeted species. Topographic diversity could also potentially serve to improve conditions for the recruitment and development of floodplain vegetation. Improving floodplain topographic diversity would benefit wildlife that is dependent on a diverse floodplain plant community.

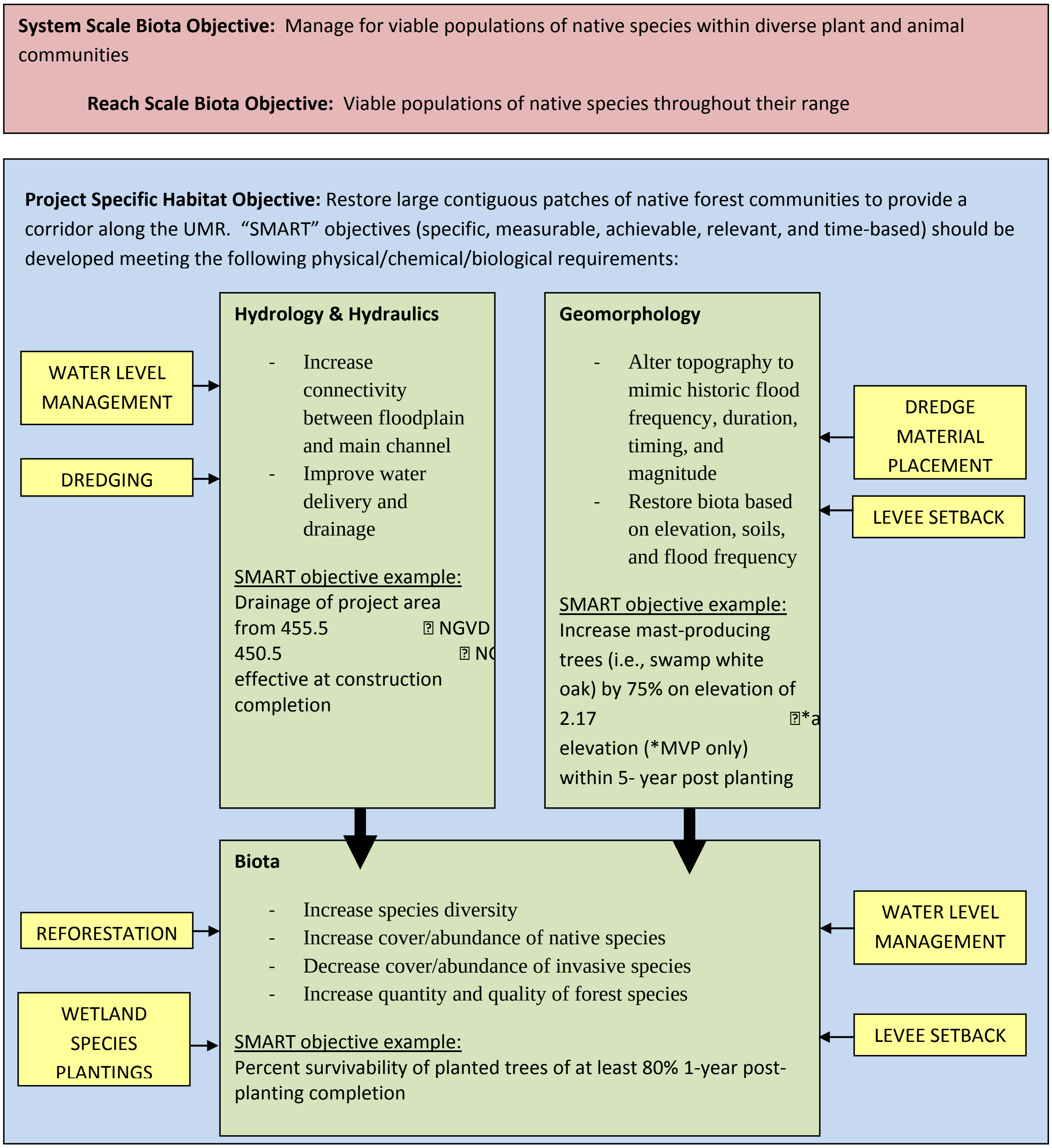


Figure 8-2. Conceptual Model for Reforestation
(Management actions are depicted in yellow.)

b. Potential Constraints. During the summer months flows are relatively high due to impoundment caused by the locks and dams. Thus, the modified flow regime does not resemble the historic (pre-impoundment) flow regime in timing, magnitude, or duration of peak flows. This has implications for both the design and possible functioning of floodplain surfaces that could be restored.

The principle constraints to effectiveness of restoring floodplain diversity will be existing flow regime and existing soil conditions. Unless the management of existing flow regime is altered to more closely mimic the historic flow regime, any effort to restore topographic diversity will not be sustainable in the long-term because the processes that create topographic diversity (scour and deposition) have not been restored. Secondly, the existing soil conditions on the site may also be limiting factor due alterations in the soil profile (e.g., permeability, type, loss of seed bank, compaction, sand lenses, etc.). Secondary constraints include the availability of substrate to restore the ridges, and the potential short-term water quality impacts of in-channel construction.

2. Design Considerations and Evaluation. It is assumed that topographic diversity (i.e., ridges) would be constructed at elevation corresponding to different magnitudes of flow, simulating a natural floodplain setting. It is conceivable that stage-discharge relationships corresponding to pre-impoundment flood flows could be developed and used to design topographic restoration. However, the existing flow regime does not often mimic the pre-impoundment hydrograph. If the restored ridges and flow regime approximated pre-impoundment conditions, it would most likely represent a scaled-down version of the historic alluvial system. That is, the restored system would be an alluvial system within the entrenched channel operating on a modified flow regime. Although not difficult to envision, designing a self-regulating system would prove to be difficult due to challenges with altering the existing flow regime. If new ridges are created or floodplain surfaces are modified, they may require bank protection to prevent erosion. Bank protection could be accomplished through the addition of rock (e.g., rip rap) imported from outside the area or with bioengineering approaches (e.g., willow mattresses, ground cover, etc.). Additionally, any topographic restoration must take into account existing soil conditions and what types of plant communities these soils can sustain. Furthermore, topographic restoration should include planting or establishing floodplain vegetation on the ridges that are able to survive and thrive on the existing soils otherwise soil enrichment may be required. It is assumed that the vegetation on the ridges would simulate a natural floodplain successional pattern. The vegetation on different topographic surfaces would correspond to flood frequency. Additional items to consider include erosion control, desired future floodplain vegetation, control of exotic species, and relationships between flow and vegetation.

Additionally, another design consideration would be how the topographic restoration measure would response to extreme peak flow events. During events of magnitude, massive erosion on the restored topographic surfaces could occur. Measures of effectiveness could include mapping of restored surfaces and associated vegetation. The primary uncertainties with restoring topographic diversity include the flow regime requirements, substrate availability for construction, effects of restored topographic features on channel behavior, and the effects of peak flows on the restored topographic features.

The effects of restoring topographic diversity on downstream and upstream geomorphic processes would need to be evaluated. If the emphasis were on modifying topographic surfaces that already exist, then the potential effects would probably be relatively insignificant. If entirely new topographic surfaces were restored, then they would change flows and geomorphic processes in an already modified system. Therefore, the latter would have higher risk and would require a more detailed evaluation.

Restoring topographic diversity is a conceptually appealing feature but it begs the question of "what is the intent of the restoration?" Is the intent to restore floodplain structure through engineering or is it to restore ecosystem processes and functions allowing the river to be self-sustaining? The former can be done, but the latter is what is needed to achieve true restoration of topographic diversity.

3. Lessons Learned

- When constructing topographic features, it is imperative to mimic the elevations currently in the adjacent area and to consider the natural slop of the river from the main channel to backwaters. In general, higher elevated islands or floodplain features work well next to channels because higher ridges are better able to withstand wave and wind action without being overtopped or eroded. Lower elevated ridges work better further off the main channel and away from high fetch areas.
- Proper placement of topographic features in relation to flow and wave action is important to ensure success. Topographic features that are misplaced relative to the flow may actually increase undesired events such as increased sedimentation in backwaters as the flow may bring in sediment-laden water, thus converting the backwater into a settlement basin.

4. Case Studies

a. Reno Bottoms (NESP Lock and Dam 8 Embankment Modification, Interim Report 2010, St. Paul District). The installation of Lock and Dam 8 and the associated embankment in 1937 permanently altered hydraulic and geomorphic conditions through the project area. It also fragmented habitat. The scope of the study focuses on evaluating project features that would modify the existing embankment to improve hydraulic conditions and natural river processes within Reno Bottoms. The potential actions to improve hydraulics and habitat discussed in the study included use of dredged material for beneficial habitat restoration. For dredging and material placement, the project would consider a combination dredging locations to include dredging in both backwater and side channel habitat. At this time (project suspended due to NESP funding), it is assumed that dredged material placement would be done in a fashion to optimize hydraulic conditions, to include channelizing flow through side channel habitat; and/or separating backwater habitat from side channel habitat. Dredged material would be placed and planted with appropriate herbaceous or woody vegetation covered based on final elevations. If constructed, this project would provide a case study for assessing environmental benefits of restored ridge and swale habitat as well as design methods.

b. Huron Island Complex HREP. The Huron Island Complex HREP is located in Pool 18 between river miles (RM) 421.2 and 425.4 in the Rock Island District). This project is currently in Feasibility. The Complex contains approximately 1,500 acres of floodplain habitat. As a result of constructing Lock and Dam 18, water levels in Pool 18 are generally higher for the entire year, flood pulses are higher, and periods of low flow formerly common during the fall have been eliminated. Consequently, about 99 percent of the Complex is located at or below the 2-year flood elevation. Under this hydrologic regime, forests stands experience prolonged inundation (>50 days) during the growing season, which results in 96 percent of the Complex being dominated by silver maple (De Jager et al. 2012).

The goal of the Huron Island Complex HREP is to increase topographic diversity through the construction of elevated tiered berms and reforestation of flood intolerant hardwood species and scrub/shrub wetland species. HEC-EFM was used to determine optimal berm heights by incorporating the growing season, hydrology, and hardwood inundation duration tolerances. The Project Delivery

Team (PDT) found a berm elevation of 535 feet would result in <25 consecutive days of inundation during a 2-year flood event. Furthermore, a second tiered berm at an elevation of at least 537 feet would provide <25 consecutive days of inundation during a 5-year flood event. These elevations are incorporated into the 2-tier berm design to provide for the greatest survival and sustainability of hard mast trees.

Semi-permanently inundated wetlands are also designed as part of the ridge and swale design. Using the same methods described above (i.e., optimal elevation heights from HEC-EFM), a ridge and swale habitat would be constructed to a minimum elevation of 535 feet using existing soils. The topographic diversity will extend just over 1,000 feet (upstream to downstream) and will be constructed with borrow from the adjacent land. Borrow can be obtained to a depth of 6 feet below surface which results in semi-permanently inundated wetlands. A draft drawing indicating this type of topographic diversity is shown figure 8-3.

c. Fox Island Division HREP. The Fox Island Division HREP is located in Pool 20 between RMs 358.5 and 353.6 in the Rock Island District. This project is currently in construction. The goals of this project include reduce forest fragmentation and enhance forest species diversity (creating topographic diversity to enhance tree plantings), enhance and expand existing wetlands (included channel excavation), and restore native grassland. The material excavated during the channel creation was used to restore topographic diversity by creating a 30-acre area 1.5 feet above existing elevation (figure 8-4). This raised area will be planted with containerized tree plantings (October-November 2012). An additional 240 acres will be planted at existing elevation. Future monitoring of this site will provide additional information on how restoring topographic diversity impacts the success of the tree plantings.

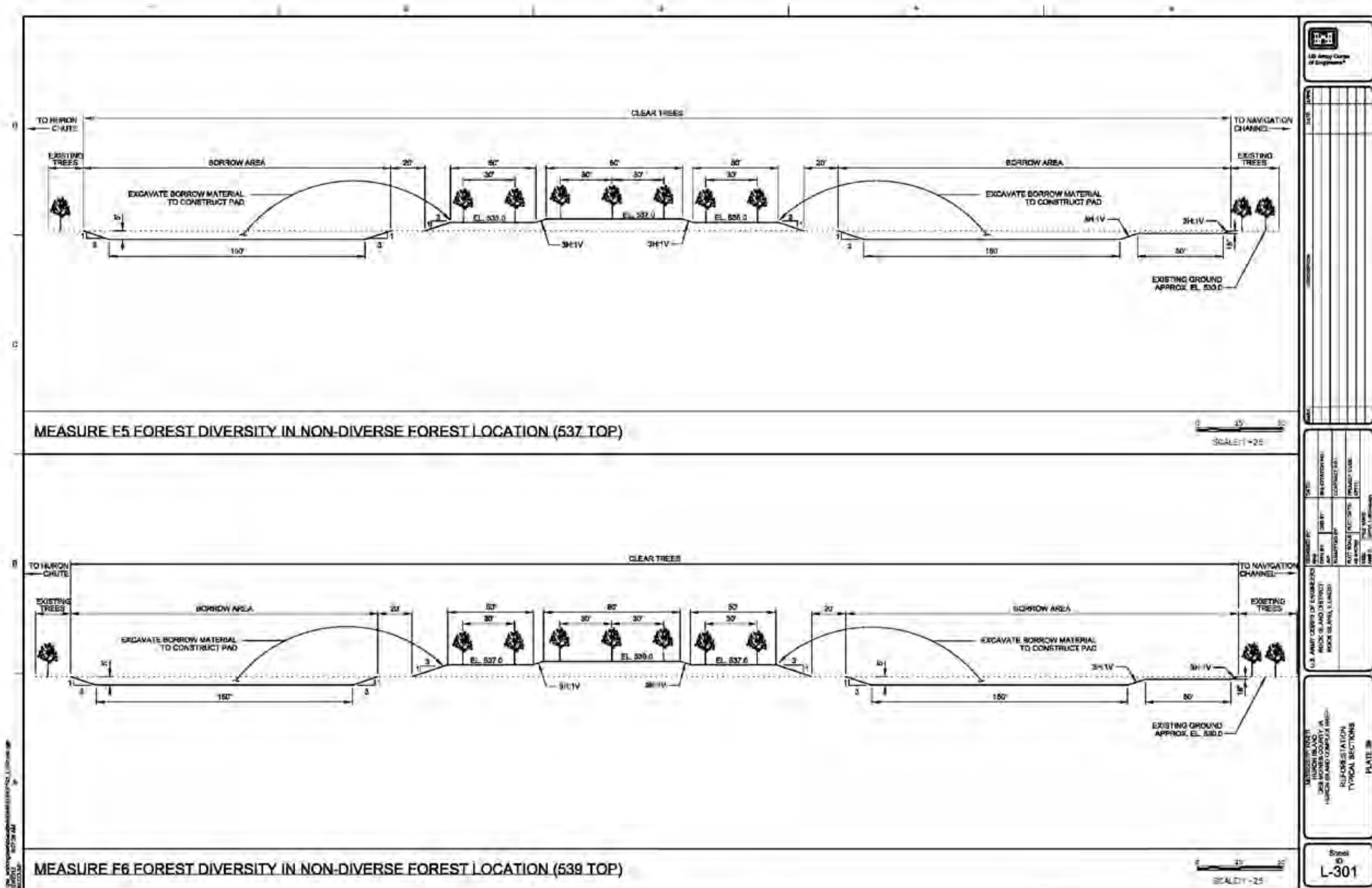


Figure 8-3. Topographic Diversity Proposed at Huron Island, Pool 18

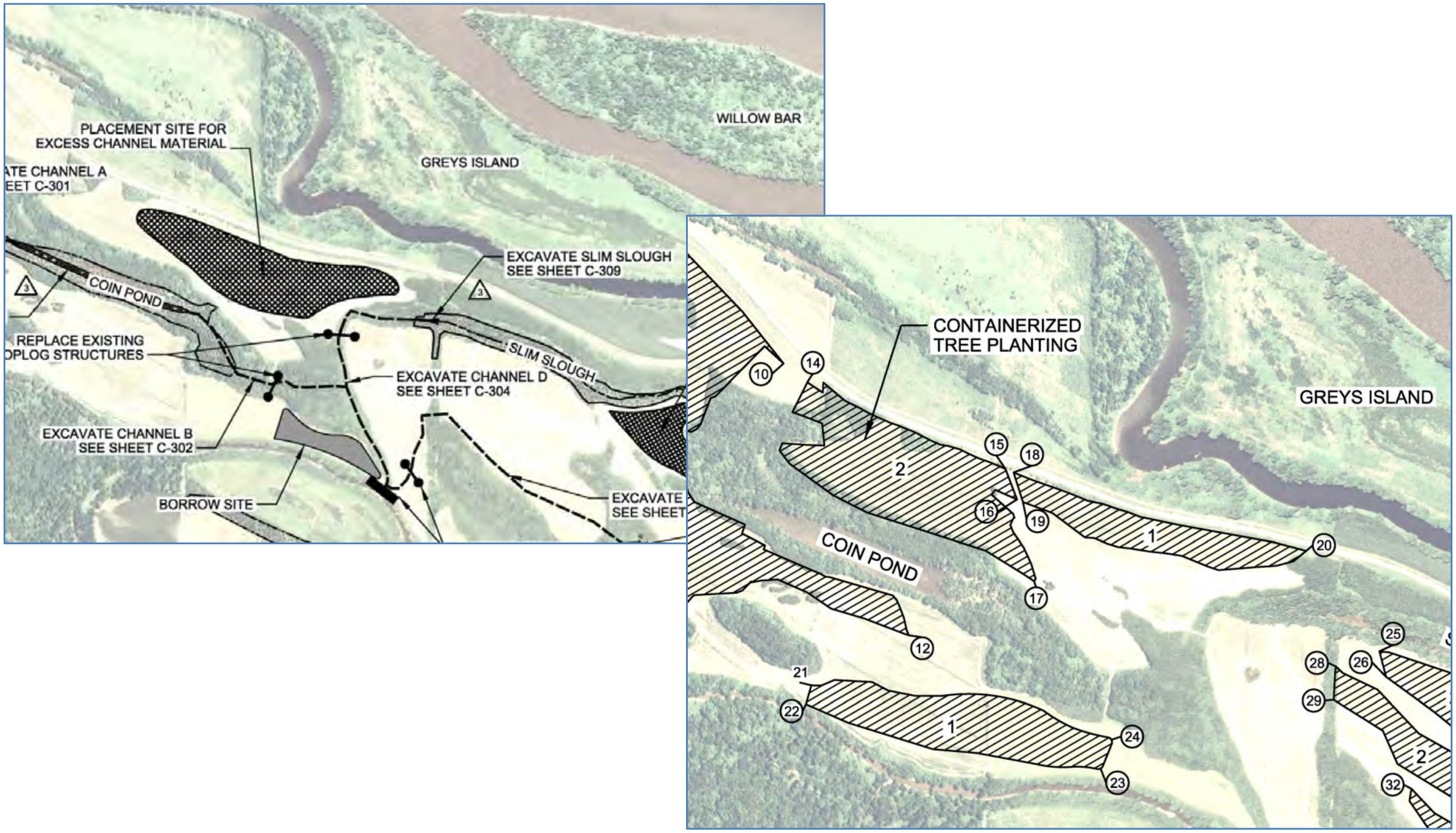


Figure 8-4. Fox Island Division HREP. Upper panel depicts location of placement site for excess channel material from Slim Slough. Lower panel illustrates location of containerized tree plantings.

D. DEPRESSIONAL WETLANDS

Depressional wetlands are constructed to create open water habitat by excavating deeper pockets within a mudflat. These pockets fill with water and allow for growth of submergent aquatic vegetation, drawing in wildlife that utilizes that habitat increasing biotic diversity. The depressional wetland may be considered a perched wetland if little to no interaction with the groundwater occurs. This makes the depressional wetland dependent on surface flows for moisture.

1. Design Methodology. Depressional wetlands can be constructed through mechanical excavation or through the use of explosives. Empirical studies by the Bellevue EMP-LTRM Field Station at Potters Marsh HREP indicate that, if designed properly, there is no difference in usage by waterfowl between the two construction methods. This study indicated that depressional wetland usage was linked to the amount of cover in the immediate vicinity of the depressional wetlands, where depressional wetlands with the best proximate cover saw the most usage by migrating waterfowl and wading birds (Gent 1997).

Additionally, the material excavated to create these wetlands may be used for berm construction or to create topographic diversity (Section C, page 8-3) further enhancing biotic diversity within the project area.

The size of the depressional wetland does matter for wildlife. If the goal of the project is to attract migrating waterfowl, then several smaller wetlands (>0.1 to <0.75 acre each) constructed in close proximity to each other has been shown to be ideal (as observed at Potters Marsh HREP). Larger depressional wetlands (>0.75 acres) appear to be used by amphibians, great blue herons, deer, and turkeys, but not waterfowl (as observed at Cottonwood Island HREP). Smaller, more numerous depressional wetlands may offer more cover since they have more bankline for the volume as compared to larger depressional wetlands. However, depressional wetlands larger than 0.1 acres are needed. Depressional wetlands less than 0.1 acres have shown to be used primarily by predators and are not considered desirable habitat (as observed at Big Timber Refuge).

Depressional wetland side slopes should be gradual, no steeper than 1V:3H; however the slope depends on the type of wetland and vegetation that is desired at the site. A slope upwards of 1V:20H (Confluence Point, St. Louis District) has been used in order to achieve the desired wetland plant community. Steep side slopes should be avoided since they are conducive to predators, but not for brood rearing or other habitat uses.

Depressional wetland depth varies from 3 to 8 feet deep. Depth does not appear to be a limiting factor for usage by migrating waterfowl. Depressional wetlands constructed at 3 to 4 feet have shown to be successfully used by migrating waterfowl at Potters Marsh HREP. If fish habitat is desired from the depressional wetland, depths should be sufficient for overwintering (> 5 feet).

Floodplain soils are very diverse. Prior to constructing a depressional wetland, a detailed soil analysis should be conducted to determine soil type, permeability, and compaction. In order to hold water within the depressional wetland the desired soils are clays (CL or CH), which have the lowest permeability of all soil types. A soil test (Atterberg Limits or Grain Size Analysis) on the material should be performed to determine what it classifies as which will assist in determining its level of permeability. The site will also need good compaction in order to improve the impermeability of the clay. A compaction test (Proctor and drive tubes) should be performed to verify whether the soils have very loose/weak clay or stiff/strong clay. Additionally, the overall site geology should be explored to identify any potential sand lens, which should be avoided to prevent draining the constructed depressional wetland. Additional soil tests and resources to consider include:

- ASTM D 698 Compaction Test (Standard Proctor Test): determines soil compaction
- ASTM D 2487 Unified Soil Classification System: outlines how soils classify and why
- ASTM D 4318 Atterberg Limits: classifies fine grained soils (clays and silts)
- ASTM D 2488 Visual Classification of Soils
- Permeability Test: only perform if a specified level of soil permeability is being used, rather than the soil type

2. Lessons Learned

- If borrow material is needed for a proposed project, designers should consider incorporating depressional wetland designs into the project, thereby gaining habitat benefits through beneficial use of borrow and placement of excavated material.
- Side slopes for depressional wetlands should be gradual. Terracing of the side slopes of larger depressional wetlands does not appear to be a cost effective practice. After a few years, the terraces erode into the wetland, leaving a bowl-shaped depression similar, if not identical, to the shape of depressional wetlands created by excavation or explosives.
- Depressional wetlands experience some sedimentation and should be constructed deeper than needed to account for this. For waterfowl use, depressional wetlands 3 to 5 feet in depth have shown to be sufficient (as observed at Potters Marsh HREP). However, at that depth it is possible that the depressional wetland would freeze to the bottom in the winter. If it is anticipated that fish would be present in the project area over the winter months, depressional wetland should be a minimum of 8 feet or deep to prevent them from freezing solid.
- Explosives regulations are prone to frequent change. It may not be possible to obtain permits to create depressional wetlands through the use of explosives. Designers should check permitting requirements in the early stages of feasibility if explosives are proposed.

3. Case Studies

a. Potters Marsh HREP. Potters Marsh is located in Pool 13 in the Rock Island District. Both mechanical excavation and explosives were used to create depressional wetlands (figure 8-5). for open water depressions within the developing mudflats and higher elevation terrestrial habitat. These holes filled with water and provide secluded open water for migratory waterfowl. Eighteen depressional wetlands were constructed (approximately 8 acres), and based on the 2003 Performance Evaluation Report, the depressional wetlands are experiencing some sloughing, but the interiors seem to be retaining their constructed depth (USACE 1992, 2003).

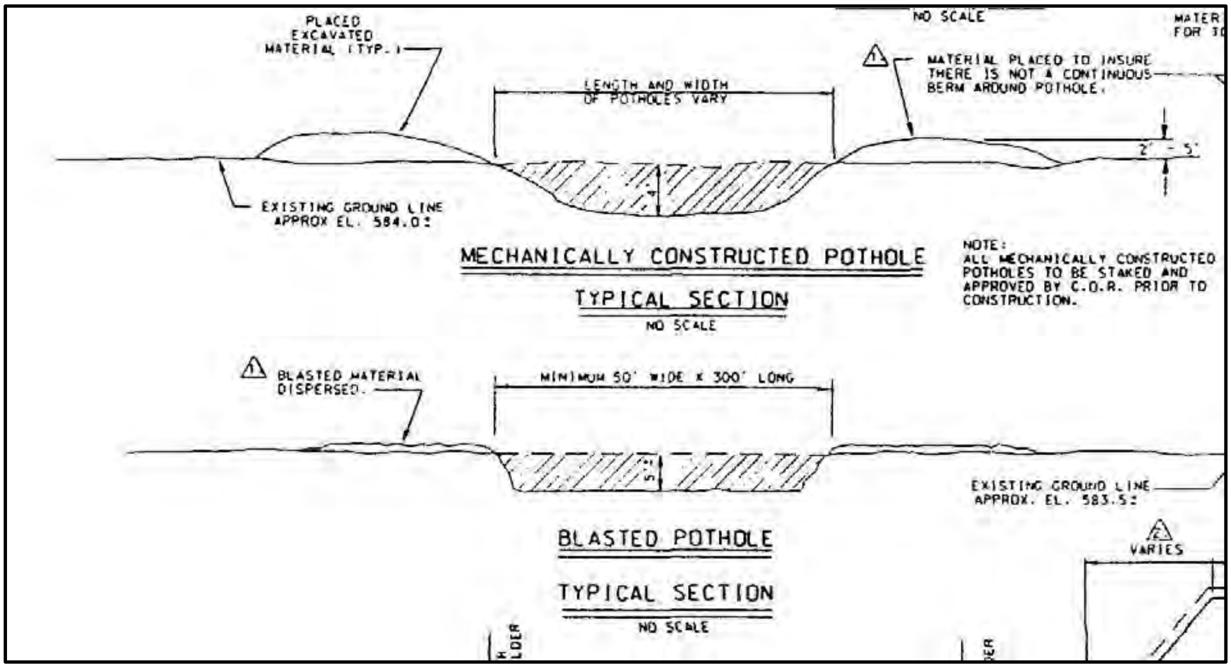
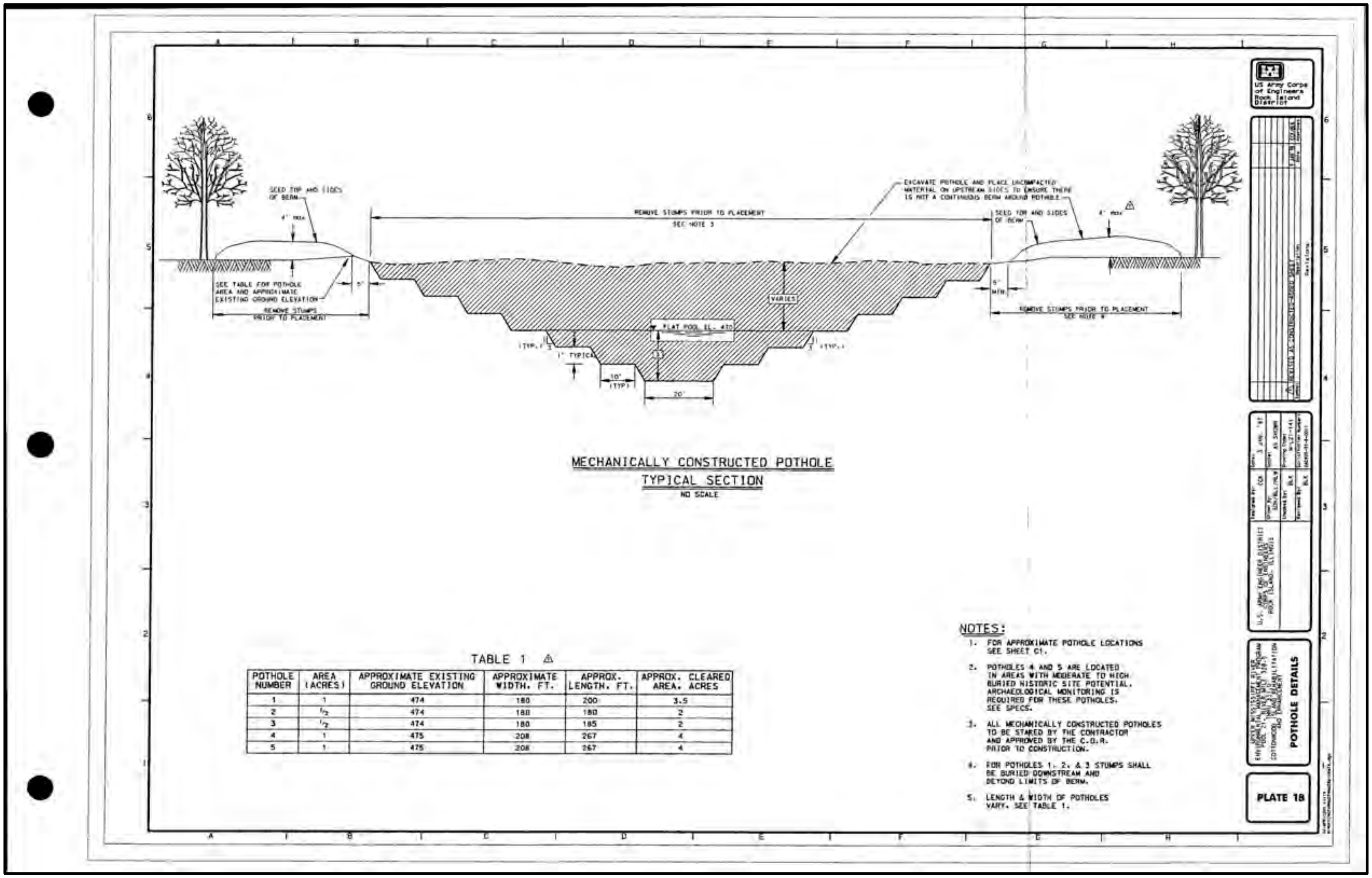


Figure 8-5. Mechanically Constructed Depressional Wetland ("Pothole") Cross Section, Potters Marsh (USACE 1997)

b. Cottonwood Island HREP. Cottonwood Island is located in Pool 21 of the Rock Island District (figure 8-6). Two 1-acre depressional wetlands, one 0.75-acre, and two 0.5-acre depressional wetlands were mechanically excavated to increase food, shelter, and breeding habitat for wildlife (USACE 1996). These are larger depressional wetlands and feature a 20-foot bottom width and final elevation approximately 3 feet below flat pool. The sides of the depressional wetland were terraced. Each terrace was approximately 10 feet wide with a 1-foot rise. The transition slop was 3H:1V. The depressional wetlands filled with water and have been used by deer, herons, amphibians, and fish; however, waterfowl use was not initially observed (USACE 2001).

During a site visit to the Cottonwood Island HREP project site on May 8, 2012, Corps personnel observed a constructed, depressional wetland (photograph 8-1) which is working as designed.



POTHOLE NUMBER	AREA (ACRES)	APPROXIMATE EXISTING GROUND ELEVATION	APPROXIMATE WIDTH, FT.	APPROX. LENGTH, FT.	APPROX. CLEARED AREA, ACRES
1	1	474	180	200	3.5
2	1/2	474	180	180	2
3	1/2	474	180	185	2
4	1	475	208	267	4
5	1	475	208	267	4

Figure 8-6. Mechanically Constructed Depressional Wetland Cross-Section, Cottonwood Island HREP (USACE 2001)

Photograph 8-1. Cottonwood Island HREP Constructed, Depressional Wetland

c. Big Timber Refuge HREP. Big Timber Refuge is located in Pool 21 in the Rock Island District. Ten depressional wetlands (0.03 to 0.08 in size) were created in mudflats using explosives to provide isolated resting, feeding and brooding areas for migratory waterfowl (figure 8-7; USACE 1989). The depressional wetlands have seen great response from invertebrates, amphibians, and small fish, and well as predators; however with presence of predators these potholes have had limited use as feeding and brooding habitat for waterfowl (USACE 1995).

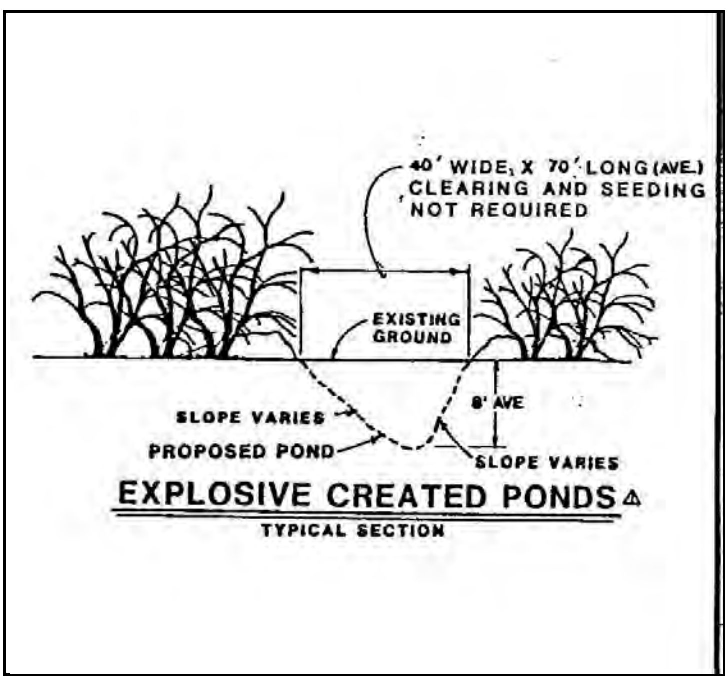
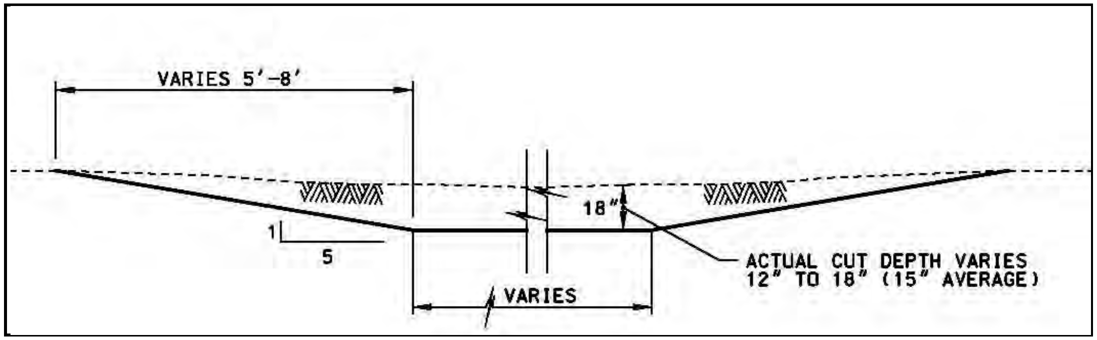


Figure 8-7. Explosive Created Depressional Wetland From Big Timber Refuge HREP (USACE 1989)

d. Lake Odessa HREP. Depressional wetlands, or ephemeral wetland, were mechanically constructed to address concerns with snake habitat loss during the enhancement of levees within the project. The project is still under construction as of May 2012, but according to the project sponsors, these wetlands are being used by various snakes and other reptile and amphibians. The design for this feature is shown in photograph 8-2 and figure 8-8.

Photograph 8-2. Depressional Wetland Constructed at Lake Odessa
Photo Courtesy of Andy Robbins, IA DNR, May 2012.



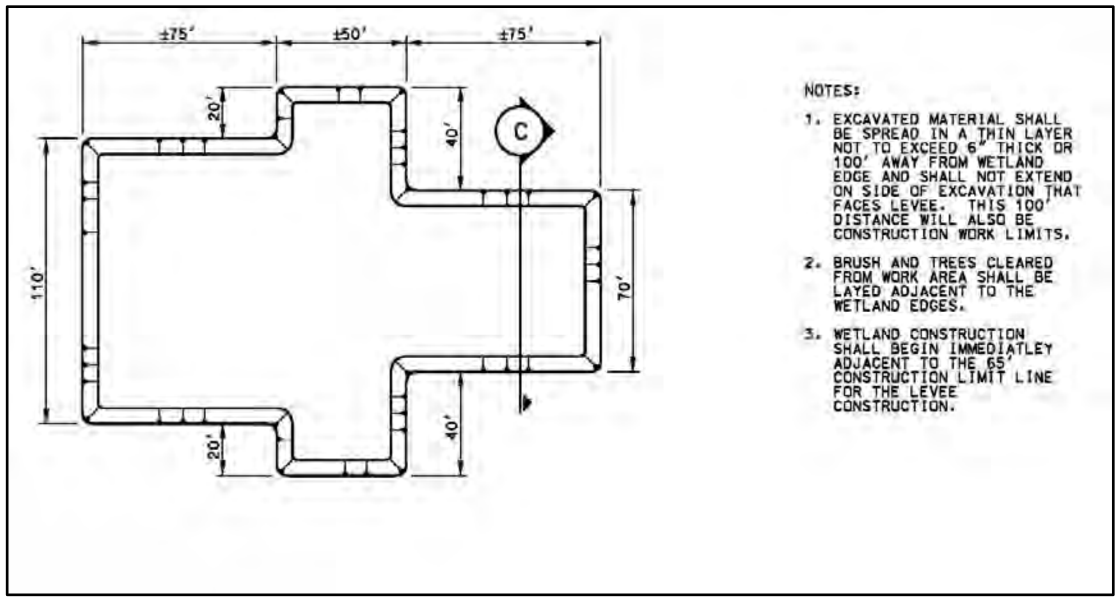


Figure 8-8. Typical Depressional Wetland Plan Used at the Lake Odessa HREP

E. REFORESTATION

The majority of forested land in the Upper Mississippi River (UMR) basin occurs in Minnesota and Wisconsin as well as southwestern Illinois and southeastern Missouri associated with river floodplains. Logging, agriculture, urban development, alterations in hydrological regimes, levees, and river impoundment have resulted in the present floodplain landscape. These changes have adversely affected tree growth on the floodplain, increasing mortality in the less flood tolerant species (e.g., pin oak), and has caused successional shifts in the remnant forest composition to species which are more flood tolerant (Johnson et al. 1974).

Today's UMRS forests represent only a small fraction of pre-European settlement floodplain forest. Seventy to ninety percent of forested floodplain habitats have been lost (Grossman et al. 2003) with the only contiguous forest cover being confined to a relatively narrow strip on the riverward side of agricultural levees (USACE 2004a). Additionally, levees have provided protection for some places to sustain hard-mast species (i.e., nut-producing trees) while other areas hold water longer killing trees. Figure 8-9 illustrates the loss of forest near Cape Girardeau, Missouri.

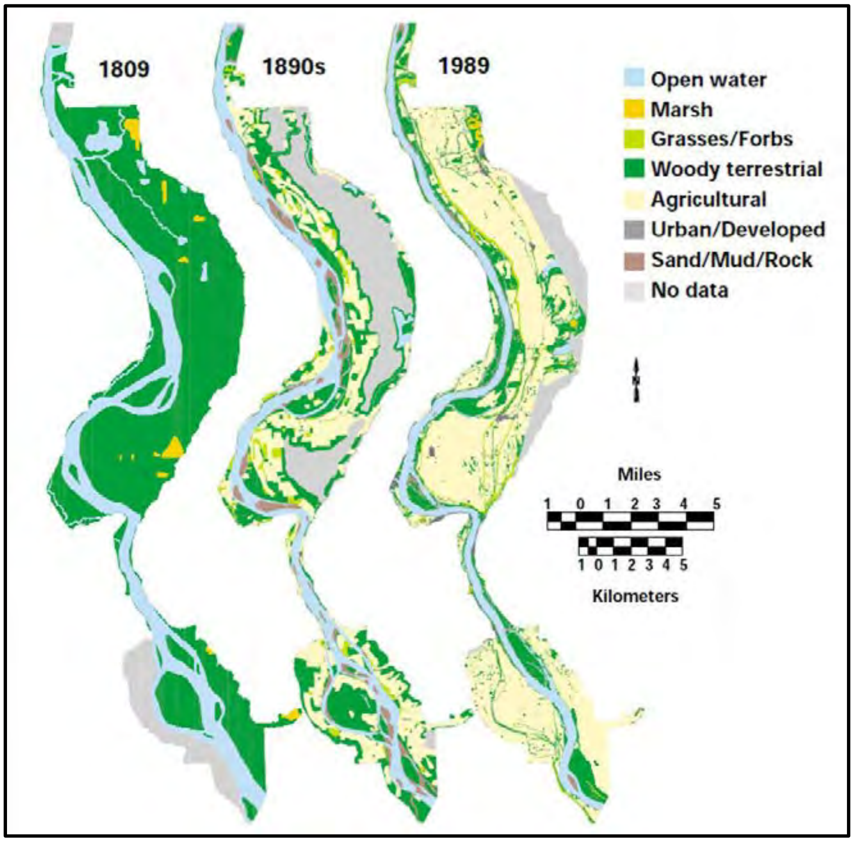


Figure 8-9. Loss of Forested Communities From 1809 to 1989 Near Cape Girardeau, MO (USGS 1999)

The Hydrogeomorphic (HGM) Classification System developed and used by Heitmeyer (2008) for the Middle Mississippi River Regional Corridor study uses hydrogeomorphic data for habitat classifications, including forest types. Forested HGM forest types are riverfront forest, floodplain forest, bottomland hardwood forest, and slope forest (table 8-1).

Table 8-1. HGM Forest Classifications (Heitmeyer 2008)

Forest Type	Location	Soils	Flood Frequency	Dominant Species
Riverfront Forest	Chute & bar surfaces; edges of abandoned channels	Well-drained sands, sandy loams, & silt loams	< 1 year in swales; 1-2 years on ridges	Early successional species: willow & silver maple
Floodplain Forest	Point bar surfaces; along tributaries	Mixed silt loams; ridge & swale topography	1-2 years on swales; 2-5 years on ridges	Successional transition: elm, ash, sweetgum, sugarberry, & box elder
Bottomland Hardwood Forest	Between floodplain forest & bluff	Silty clays	2-5 years	Varies by elevation; from bald cypress-tupelo swamps in low lying areas to oaks and hickories in highest elevations
Slope Forest	Alluvial fans and higher terraces	Erosional sources &alluvium	Rarely	Diverse mix of species common to upland and floodplain communities.

1. Design Methodology. The Corps employs foresters who are responsible for maintaining forested lands owned by the Corps. The following design methods provide a summary of some of the techniques used during reforestation; however, during the planning process the PDT should consult the foresters. Additionally, a set of modeling tools are available to assist in selecting sites, tree species, and tree sizes for successful reforestation. These flood potential models for the Upper Mississippi and Lower Illinois Rivers are available from USGS at http://www.umesc.usgs.gov/reports_publications/psrs/psr_2001_01.html. Additional resources on reforestation techniques and practices include:

- Schweitzer, Callie J.; Stanturf, John A.; Shepard, James P.; Wilkins, Timothy M.; Portwood, C. Jeffery; Dorris, Lamar C., Jr. 1997. Large-scale comparison of reforestation techniques commonly used in the lower Mississippi alluvial valley: first year results. In: Pallardy, Stephen G.; Cecich, Robert A.; Garrett, H. Gene; Johnson, Paul S., eds. Proceedings of the 11th Central Hardwood Forest Conference; Gen. Tech. Rep. NC-188. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 313-320.
- Allen, J.A.; Keeland, B.D.; Stanturf, John A.; Clewell, A.F.; Kennedy, Harvey E.. Jr. 2001. A Guide to Bottomland Hardwood Restoration. Gen. Tech. Rep. SRS-40. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 142 p.\
- Stanturf, J.A., S.H. Schoenholtz, C.J. Schweitzer, J.P. Shepard. 2001. Achieving restoration success: Myths in bottomland hardwood forests. Restoration Ecology. 9(2): 188-200.

Many states in the UMR basin have published forestry best management practices, which provide technical guidelines for implementing forestry practices while protecting forest, soil, and water resources. Links to published forestry best management practices for the five UMRS states are listed below:

- Illinois (IDNR 2000): http://web.extension.illinois.edu/forestry/publications/index.html
- Iowa (IDNR 2004): http://www.iowadnr.gov/forestry/bmps.html
- Minnesota (MFRC 2005): http://www.frc.state.mn.us/initiatives_sitelevel_management.html
- Missouri (MDC 2005): http://mdc4.mdc.mo.gov/Documents/441.pdf
- Wisconsin (WDNR 1995): http://www.dnr.wi.gov/forestry/Usesof/bmp/

The Corps' forest management program has focused on planting larger stock trees to enhance survivability. The annual flood pulse of the Mississippi River often will kill up to 75 percent or more of seedling plantings. Mowing and herbicide can be applied to plantings, but equipment access can be limited.

Reforestation requires an understanding of individual site quality (e.g., soils, water regime, and elevation) and species requirements. During the planning the following need to be taken account 1) species intolerance to flood regimes, 2) light requirements and availability, 3) herbivory, 4) poor seedling quality or seed, and 5) species-species interactions (Henderson et al. 2009). Misunderstandings have the potential to lead to large-scale planting failure.

a. Containerized and Root Production Method®. The RPM® or container grown technique creates large seedlings that may be more conducive to surviving the potentially harsh conditions found on the floodplain. These seedlings have dense fibrous roots (photograph 8-3), and studies have shown that these seedlings have larger initial basal diameter, greater height and survival rates, and produce acorns faster as compared to bare root seedlings, (Lovelace 2002; Dey et al. 2004). However, a study conducted by the Henderson et al. (2009) found no difference in survival between bare root seedlings and RPM®, and relative growth rate of RPM® seedlings was lower than bare root which suggests that even though the seedlings have a head start in terms basal diameter, they do not necessarily grow at significantly higher rates. Cost of RMP® trees is higher, but they are larger trees which can be planted at a wider spacing, potentially saving on overall costs. Consultation with foresters is recommended when selecting planting stock method for a proposed project.

Photograph 8-3. RPM® Root Mass (Left) Compared to Bare Root Mass (Right)
(FK Nursery Library, 2012)

b. Soil Mounding . Soil mounding creates small differences in elevation altering the site suitability for tree seedling establishment and growth (Schoenholtz et al. 2005) by improving drainage and increasing the overall height above flood water levels for species less tolerant of flooding (Dey et al. 2008). However, this technique of "soil mounding" has also been shown not to improve tree height, diameter growth, or survivability (as compared to unmounded; Dey et al. 2004; Dey et al. 2008; Henderson et al. 2009).

The soil properties play an important role in determining if soil mounding is needed. Soils that are loamy and fairly well drained may not need mounding (Dey et al. 2004). In the St. Paul District, based on a 2003 survey, the average minimum elevation above mean pool elevation where swamp white oak occurs is 2.17 feet, and for black oak is 3.01 feet. These values provide a rough guideline on appropriate elevations for these species to succeed in this latitude.

c. Tree Species. Selection of trees species is dependent on site conditions (e.g., elevation, flood frequency, and soils). The hard-mast species planted (depending on latitude) may include Bur Oak, Swamp White Oak, Pin Oak, Northern Pecan, Shellbark Hickory, and to a limited extent, Walnut and Northern Red Oak . Other species found on the floodplain include Persimmon, Hackberry, and Green Hawthorne. Other trees with "winged fruit or light-seeded" (Ash, Box Elder, Cottonwood, Silver Maple and/or Sycamore) could invade creating a diverse forest community. Stanturf et al. (2000) suggested wind and flood dispersal of light-seeded species might occur up to 100 m from established sources.

d. Seed Source. It is recommended to collect seeds within a one hundred-mile radius of the planting site, adapted to local weather conditions and flood frequency. It is not recommended to use a seed source from an upland site (USACE, 2012).

e. Competition. Competition from herbaceous plant species may be problematic for planted tree seedlings. Various techniques can be used to reduce competition. Techniques may include placement of degradable ground cover mats or use of herbicides. Ground mats are exclusively used with RPM® stock seedlings, and should not be used with bare root seedlings. Ground cover mats have been used in the past to reduce competition. However, Missouri Department of Conservation has observed that ground cover mats do not work well in areas that flood due to the floodwaters stripping the mats or that mats become entangled and potentially strangling the seedling. Additionally, the Corps foresters are moving away from the use of ground mats due to their ineffectiveness. The Corps foresters recommend the use of herbicides during early tree establishment, but use may be limited by flooding durations. Herbicides can be used with both RPM® and bare root seedlings.

Fertilization after tree seedling establishment would increase survival and enhance growth (USACE, 2012). There is potential for invasive species like reed canary grass to out-compete tree seedlings and form dense monocultures inhibiting tree growth. Active management of reed canary grass may be necessary to increase tree planting success.

f. Herbivory. Herbivory by deer and small mammals poses an additional threat for natural and artificial tree regeneration. Deer browsing can be a primary source of tree seedling mortality. The use of protective measures such as stem guards, ground mats, fencing, tree shelters, and other types of exclosures can limit browse damage in tree plantings. However, voles and other burrowing animals tend to hide in ground cover mats for cover and then their predators ruin the mats trying to get to their prey. This ruins the ground cover mats and any protection they may have initially provided. Tree shelters can be used to protect the seedlings if deer damage is expected to be severe. Tree shelters come in various heights. Four to five foot tubes are good for areas with high deer damage, while shorter tubes (2-3 feet) may be adequate for protection from other animal damage (girdling of lower stems and/or roots from voles and other rodents). Tree wrap and rodent repellants are other options that could be used to reduce herbivory. According to Corps foresters, certain types of tree wraps can be detrimental to long-term tree health by trapping sediment around the base which reduces the basal oxygen exchange. Therefore use of tree wraps should based on site-specific conditions. Rodent repellants must be re-applied every time it rains, leading to increase costs and labor.

2. Lessons Learned

- Tree mortality along the UMR has been positively correlated with flood duration and amplitude. After the 1993 flood, some areas near St. Louis, Missouri experienced between 80 to 100 percent mortality of seedlings. Flood tolerance of trees is species specific therefore in sites that have a high flood potential planting more flood tolerant species is recommended.

- In the St. Paul District, tree plantings have been successfully established in both the spring (mid-April to mid-June) and fall (mid-October to mid-November). Seedling availability from nurseries is usually better in the spring.
- Tree plantings need weed control for a minimum of three years. Ground cover mats are no longer recommended for use. Use of herbicides is needed during early tree establishment.
- Tree shelters require regular maintenance. Environmental factors can damage them. Other vegetation can grow up inside the tube and choke out the tree seedling. Additionally, in low elevation, tree shelters may collect significant amounts of sediment during flood events, potentially causing seedling mortality. Tree shelters should be avoided where prescribed fires is to be used within five years of project completion. Tree shelters must be properly installed so as not to leave a gap at the base of the tree for rodents to enter.
- If possible, avoid row planting of tree seedlings to make the site look more natural and improve aesthetics. Missouri Department of Conservation suggests randomly planting seedlings or plating them at 45 degree angles from the river so that rows are not as evident.
- Quality assurance is very important during contract planting operations to ensure seedling survival and success. Among the critical items to check for is how well the planting stock was protected during storage and handled during planting. The sensitive roots of seedlings must be kept cool, moist, and out of the wind and sun from the moment they are lifted out of the nursery bed until they are covered with soil in the transplant location.
- Quality assurance is also very important in verifying the source of planting materials.
- Fine sediments with a high percentage of clay may be more difficult to establish trees on. This is especially true if there is significant compaction from heavy equipment during construction. One potential solution is the use of power augers during tree plantings to loosen the soil in the planting hole.
- When planting containerized trees in high clay content (>60 percent) hydric soils berms should be used. When a depression is created in these soils (planting a container tree) and a rainfall event occurs water accumulates in these depressional areas and creates a small pond in which the roots are submerged for extended periods of time thus effectively reducing root growth due to the lack of available oxygen. When planting the same container tree in a berm you actually set the container on top of the surface and surround it with soil thus providing more air to the roots more quickly after a flood or rainfall event.
- Do not plant hard mast trees where soil hydrology and pH has to be altered. Hard mast trees grow on well-developed alluvial soils and pioneering tree species (soft mast) colonize newly-developed alluvial soils (near riverfronts and areas of high sediment deposition).
- Hard mast trees colonize elevated areas with herbaceous understory (i.e., grass) in large river floodplains.
- Levees along the Lock and Dams have altered the soil hydrology changing the pH of floodplain soils, which ultimately affect which tree species can be planted.

3. Case Studies

a. Bay Island HREP. Bay Island is located in Pool 22 between RM 311.0 and 312.0 in the Rock Island District. The Bay Island project was constructed to provide high quality, dependable wetland habitat for migratory waterfowl. Water level management capabilities were achieved through constructing a levee system, pump station, and water control structures. Approximately 30 acres within the two created wetland management units were planted with mast trees (figure 8-10).

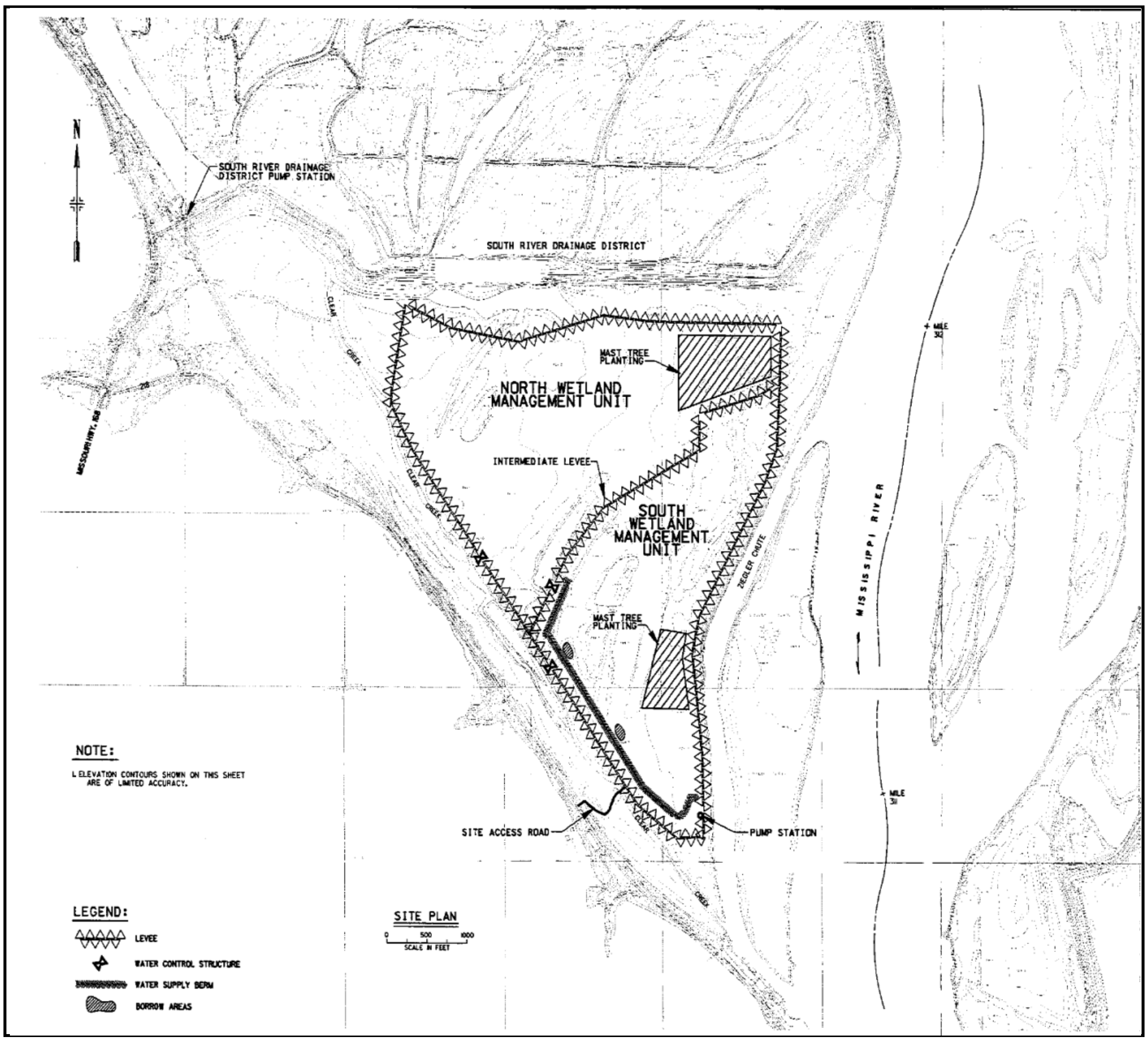


Figure 8-10. Location of Tree Plantings for the Bay Island HREP (USACE 1999a)

In 1994, pin oaks were planted in a unique design to test alternative methods for establishment of mast trees on Mississippi River bottomland sites. Four planting techniques were tested: (1) planting container-grown tree stock; (2) planting bare-root tree seedlings with tree shelter protection; (3) planting bare-root seedlings without shelter; and (4) planting acorns. Immediately after tree planting was complete, 1/100 hectare permanent monitoring plots were established within each reforestation area. The permanent sampling plots were recovered and remeasured in October 1995.

The first year results (1995) showed that even with an overtopping flood, by October 1995, overall survival of the 450 container grown trees planted on the 4-acre plots was 99.3 percent. Acorn survival from sample plots was 45.7 percent, yielding 944 seedlings per hectare. Survival of bare-root seedlings, both sheltered and non-sheltered, was 84.2 percent with 978 trees per hectare. Due to the flood, most of the tree shelters (63 percent of the sheltered trees) were washed away. Trees that initially had shelters for the first 6 months and then had the shelters washed away by flood waters had only 70.3 percent survival rate (USACE 1999a). The initial performance evaluation report recommended pursuing more mast tree plantings that consist of container-grown or balled and burlapped trees. If seedlings or acorns are used, the layout should be coordinated with the local sponsor who will be maintaining the site to ensure that trees are clearly marked and appropriately spaced for the mowing equipment to be used at the site (USACE 1999a).

By 2002, flooding events hampered overall success of mast-tree plantings (USACE 2002a). Only about a dozen trees were still growing from the original plantings that included approximately 7,500 acorns and seedlings in a 10-acre area. In 2000, the Missouri Department of Conservation planted new trees to do a direct comparison between RPM® and bare-root trees. Tree berms in the south wetland management unit were planted with RPM® trees, alongside 100 two-year old bare root stock seedlings (USACE 2002a).

b. Thompson Bend Riparian Corridor Project. The Thompson Bend Riparian Corridor Project is located between Mississippi River RM 30.to 5.0 in the St. Louis District. In this stretch of the Mississippi River flows in a broad sweeping reverse curve just above the confluence with the Ohio River (figure 8-11). This area has been susceptible to severe flooding and there is high risk that the Mississippi River will create a channel cut-off and form a new, shorter, steeper, high velocity channel with resultant changes upstream and downstream. In the early 1980s, the Corps and an organization of local landowners developed a plan using traditional (e.g., riprap) and innovative measures to minimize scour and erosion. The innovative design included successive lines of vegetative perpendicular to the flow-line across the neck of the curve and in, January 1986, began plantings of different species of trees and shrubs that eventually totaled over 125 acres (on private lands). The theory was flood velocities would decrease at each successive tree line, thus limiting scour and erosion and encouraging deposition. The Flood of 1993, however, destroyed much of the project. Trees 60 to 70 feet tall were bent over and completely submerged for months. The trees died but remained rooted in place preventing erosion. Even though damage occurred, the estimate following this flood was more net gain of soil due to deposition than loss due to scour. Flow measurements showed velocities were decreased by almost half by each successive tree line. The Corps purchased easements from landowners to restore and enhance the destroyed tree lines and is responsible for both planting and initial maintenance of the trees.

In 2011, continued plantings occurred using a mix of cottonwood, sycamore, and overcup oak. Pre-tree planting efforts included summer mowing, herbiciding, and planting a cover crop of redtop (*Agrostis gigantean*), Virginia wild rye (*Elymus virginicus*), and partridge pea (*Chamaecrista fasiculata)*. In the fall, bareroot sycamore seedlings (n = 5,101) and cottonwood cuttings (n = 5,101) on 10 x 10 foot staggered spacing were planted. Overcup oak seedlings (n = 1,134) were interplanted throughout the area to obtain an even distribution. Total planting area was 26 acres. In 2012, follow-up application of a pre-emergent/post-emergent herbicide will occur within tree rows.

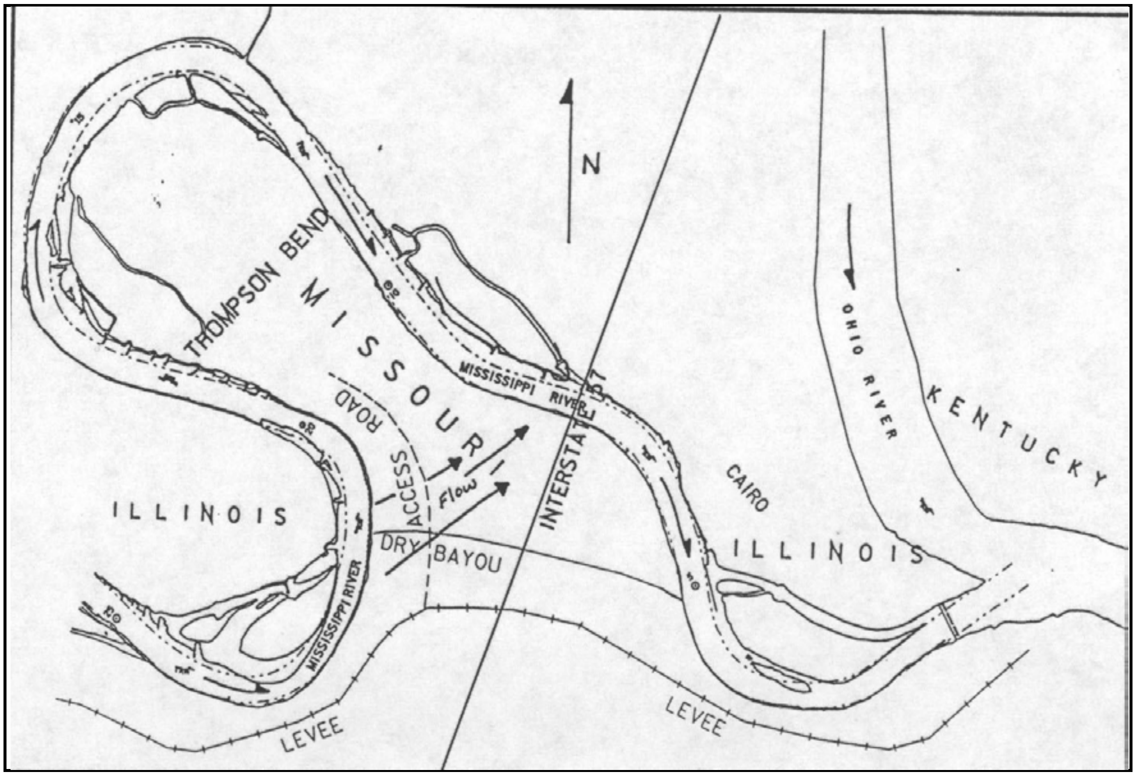


Figure 8-11. Thompson Bend Riparian Corridor Project Location.

c. Brown's Lake. Brown's Lake is located in Pool 13 in the Rock Island District between RMs 544.0 and 546.0. One feature of this project involved placement of dredged material into a terrestrial site to depths of 6 to 8 feet and re-planting with mast production trees. One of the project goals was to establish bottomland hardwood.

In May, 1990 a 150 foot wide strip immediately adjacent to the upstream dredge material containment levee was direct seeded with pin oak acorns. Approximately 25,000 acorns were dropped by helicopter onto this 150 foot wide strip. On May 20, 1991 a strip survey of this area was conducted by the Corps. Strips three feet wide and fifteen feet apart were surveyed for pin oak seedlings. Based on this survey it is estimated that 1200 pin oak seedlings were growing on the site at this time. The pin oak seeding immediately adjacent to the upstream containment levee was somewhat successful. Approximately 5 percent of the acorns dropped produced seedlings after the first year.

These seedlings have since died from extended inundation in 1992 and 1993. This site was re-planted with mast producing hardwoods in June 1992. No planting of trees within the placement site was successful before this time due to consolidation and drainage problems. Future projects which consider dredged material placement sites for reforestation should include design of a drainage system for the placement site.

In addition to the objective of increasing bottomland hardwood diversity this project has the secondary objective of developing valuable data regarding the planting of mast production trees on dredged material deposits. Iowa State University has been contracted to plant the trees and monitor their survival with the following objectives in mind:

- evaluate species suitability based on growth survival,
- evaluate the use of nurse crop species on early growth survival of trees,
- evaluate the use of different kinds of seedling stock types on early growth and survival of trees, and
- evaluate the use of applications of sewage sludge and fertilizer on early growth and survival of trees

Only species native to the region were selected for planting. Species known for their value as wildlife food were given priority for planting. Two kinds of plots have been established on the study site. The first consists of smaller 16-tree plots that will test the suitability of 13 different mast producing species for planting on this site. The second kind of plot is large and in total covers most of the area. These plots were planted with 3 mast-producing species (Black Walnut or Shellbark Hickory, Red Oak and Bur Oak). Nested within these plots are subplots to test the use of sludge as an organic amendment, the use of nurse crops to control competition, and the use of fertilizer to increase growth rates.

Conclusions. The technique of aerial pin oak seeding immediately adjacent to the upstream containment levee was somewhat successful. While creation of the dredged material containment area did succeed in raising the elevation of the placement site, much of this area remains too poorly drained to be suitable for regeneration of mast-producing tree species. Mast trees planted as part of the ISU revegetation study are growing on sites in the containment area that are relatively higher in elevation and better drained than the surrounding ground. This mast tree component currently occupies only a small percentage of the replanted area. Persistent poor drainage in much of the containment area limits the likelihood that further active mast tree revegetation efforts would be successful. Natural revegetation of the area by wet-soil adapted tree species such as willow and cottonwood appears to be underway. Over time, further consolidation of the dredged material may provide more favorable conditions for mast tree production. Although some mortality of the mast trees currently established on the site will continue to occur, those that survive to maturity could provide a future seed source for natural mast tree regeneration in the long term.

d. Long Island Division (Gardner Division). Long Island Division is located in Pool 21 in the Rock Island District between RMs 332.5 and 340.2. Two of the project objectives were to; reduce forest fragmentation, and to increase bottomland hardwood diversity. The project area also has one of the last high quality stands of bottomland forest in the middle reaches of the UMR. In order to meet the objectives it was decided to plant 67 acres of mast-producing trees on the dredged material placement site located on Long Island's eastern agricultural field.

Completion of mast tree planting on the 67 acres of Long Island's 184-acre eastern agricultural field with the highest elevation was in 2004. This planting area is where the dredge disposal from O'Dell Chute channel dredging was deposited and incorporated into the soil. Trees specified to be planted included 1005 pin oaks, 670 swamp white oaks, 670 bur oaks, 670 northern pecans, and 536 sycamores for a total of 3,551 trees. The trees were planted at 30-foot intervals on berms parallel to O'Dell Chute. The berms were 30 feet apart. All trees were to receive weed barrier mats and the trees were at least 5/8-inch caliper and 5 feet high.

A meeting was held on 12 November 2003 at the reforestation site on Long Island to inspect the mast tree plantings and assess the success and condition of the previous two plantings. The team had concerns about tree survival due to the abundant weed growth. The tree plantings appeared to have good survivability, but were stressed by the amount and height of weeds around them. The tall weeds have the potential to lay over the tree plantings stunting their growth or killing them. It was decided to use herbicide and seeding options to aid in the tree's survival. It was suggested that in future mast tree plantings, that berms be seeded as well as the rows between the berms.

During a later inspection, District foresters felt that the flooding helped manage the weeds around the mast trees and will give the trees a better survival rate. In 2006, Missouri Department of Conservation personnel visited the site and could not find any of the seedlings due to competition. Common ragweed at the time of the visit was approximately 12 feet tall.

The Long Island HREP project site was re-visited on May 8, 2012 by Corps and FWS personnel. The site visited included walking to several areas of planting. Some success of direct planting was noted at the site, with trees planted on lower elevations having a higher success rate. The plastic used to protect the roots and lower trunk of the planted trees has not deteriorated at all in the 8 years since the original planting. The growth of some of the trees has been stunted by the plastic as shown by visible ridges where the plastic cuts in to the trees. Figures 8-12 and 8-13 and photographs 8-4a, 8-4b, 8-4c, and 8-5 illustrate plans and photos for the site.

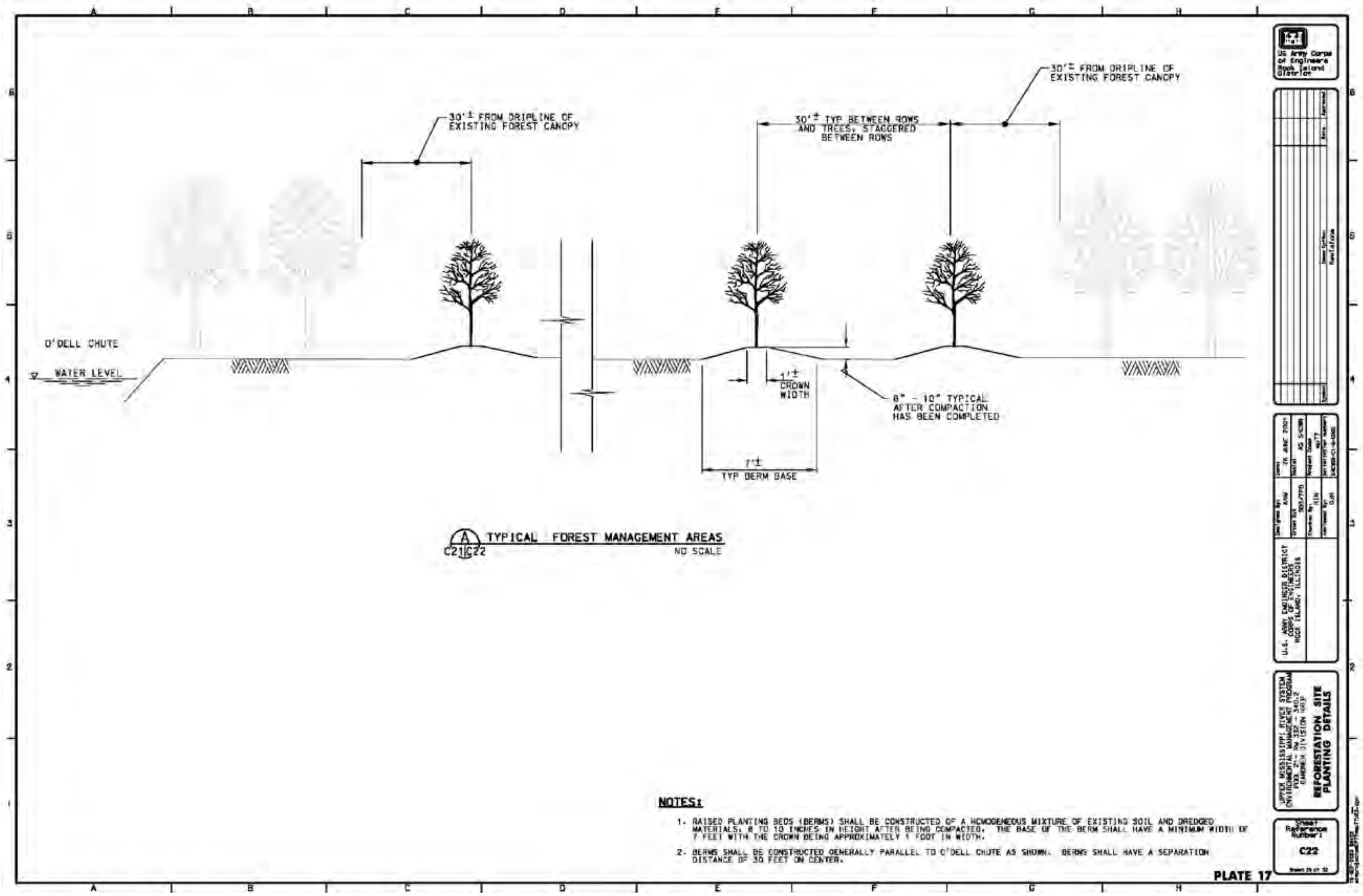


Figure 8-12. Tree Planting Design for the Long Island Gardner Division HREP

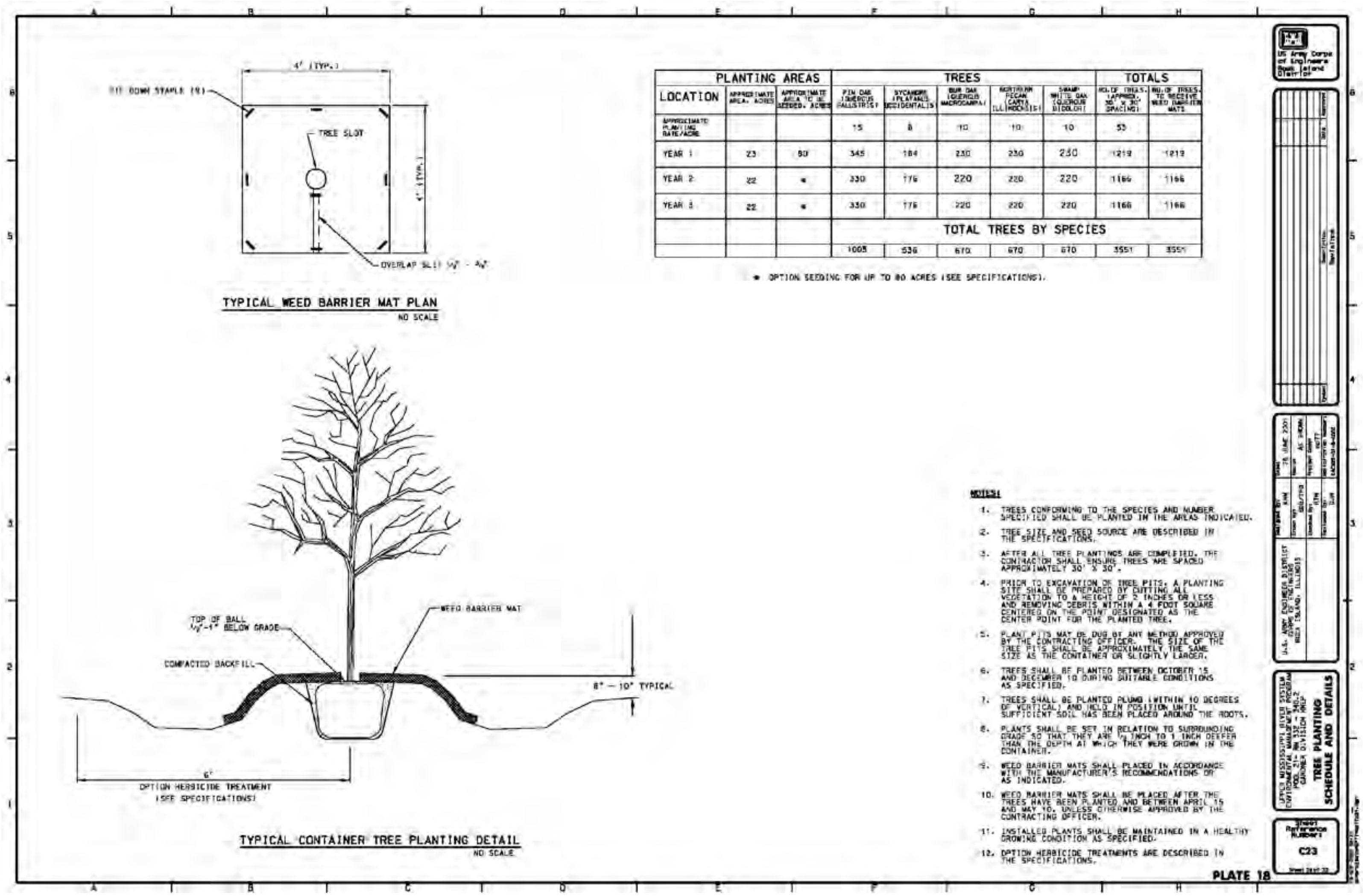
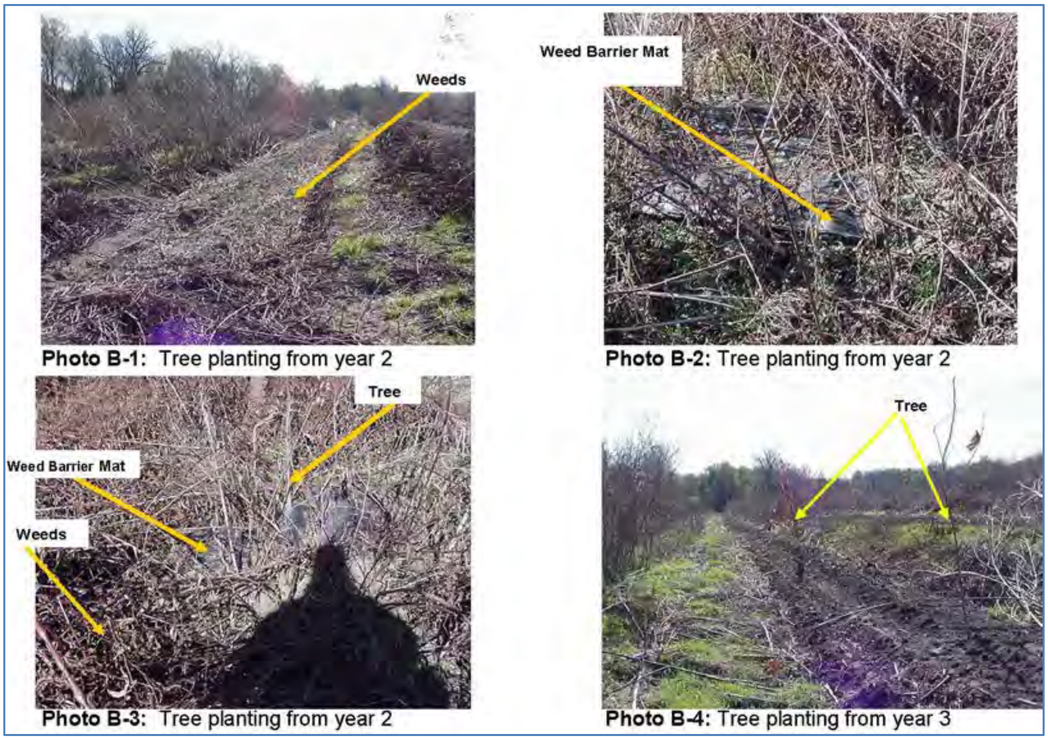


Figure 8-13. Tree Planting Design for the Long Island Gardner Division HREP



8-4a

8-4b

8-4c

Photograph 8-4. Long Island Gardner Division HREP Tree Plantings

Photograph 8-5. Plastic "Burlap" Placed Around Base of Tree

e. Cottonwood Island. Cottonwood Island is located in Pool 21 between RMs 328.5 and 331.0 in the Rock Island District (figures 8-14, 8-15, and 8-16). One of the project objectives was to increase bottomland hardwood diversity and quality. The features used to obtain this objective were the planting and attempted establishment of trees in existing management/crop areas and on elevated ridges. Several sites were been selected for planting throughout the project area. Restoration of a mast-producing tree component to these areas would provide wildlife with an additional winter food source for a period of up to 100 years. Pin oak, swamp white oak, bur oak, pecan, and sycamore would be planted on 30-foot spacing. species would be intermixed at each site to avoid solid blocks of individual species.

Large stock seedlings greater than 4 feet high would be planted to introduce a component of mast-producing trees to the project area. The tree plantings would be spaced and distributed to allow for a natural appearance. This enrichment planting technique differs from a plantation tree culture, where the objective would be to make mast-producing trees the dominant species. Instead, enrichment plantings are designed to introduce a component of mast-producing trees to create a mixed forest stand.

Pin Oak, Sycamore, Bur Oak, Northern Pecan, and Swamp White Oak were planted at designated locations at each planting site. Ground disturbance for mast tree planting occurring on previously harvested forest management areas consisted of cutting and removing all woody vegetation within 6 feet of the center point for the planted tree and then excavating a planting hole 2 feet in depth and 3 feet in diameter. Tree planting operations within the agricultural field involved disking to a depth of 4 inches, this was followed by excavation of planting holes. The forest management areas maintained a natural appearance throughout the establishment process, as only the vegetation directly surrounding the seedling was controlled. On the dredged placement site, soil disturbance for tree planting was limited to the newly placed material only. A cover crop of red top grass and annual grains was to be established in the tree planting sites to help control unwanted weed species. Herbicides were used to control any competing vegetation. After a 3-year establishment period, the surrounding ground in all planting areas was allowed to assume natural regrowth.

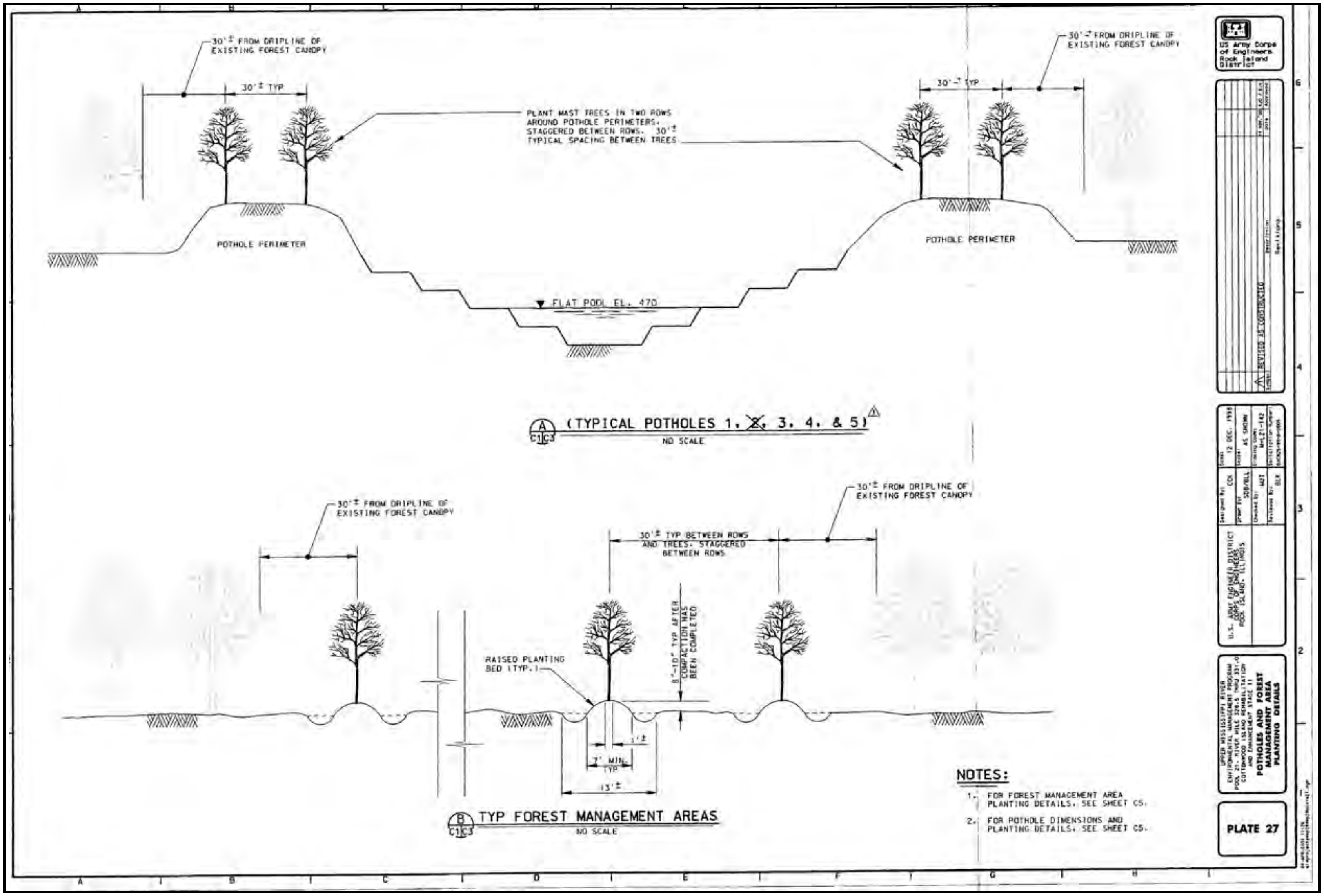


Figure 8-14. Forest Plans for Cottonwood Island

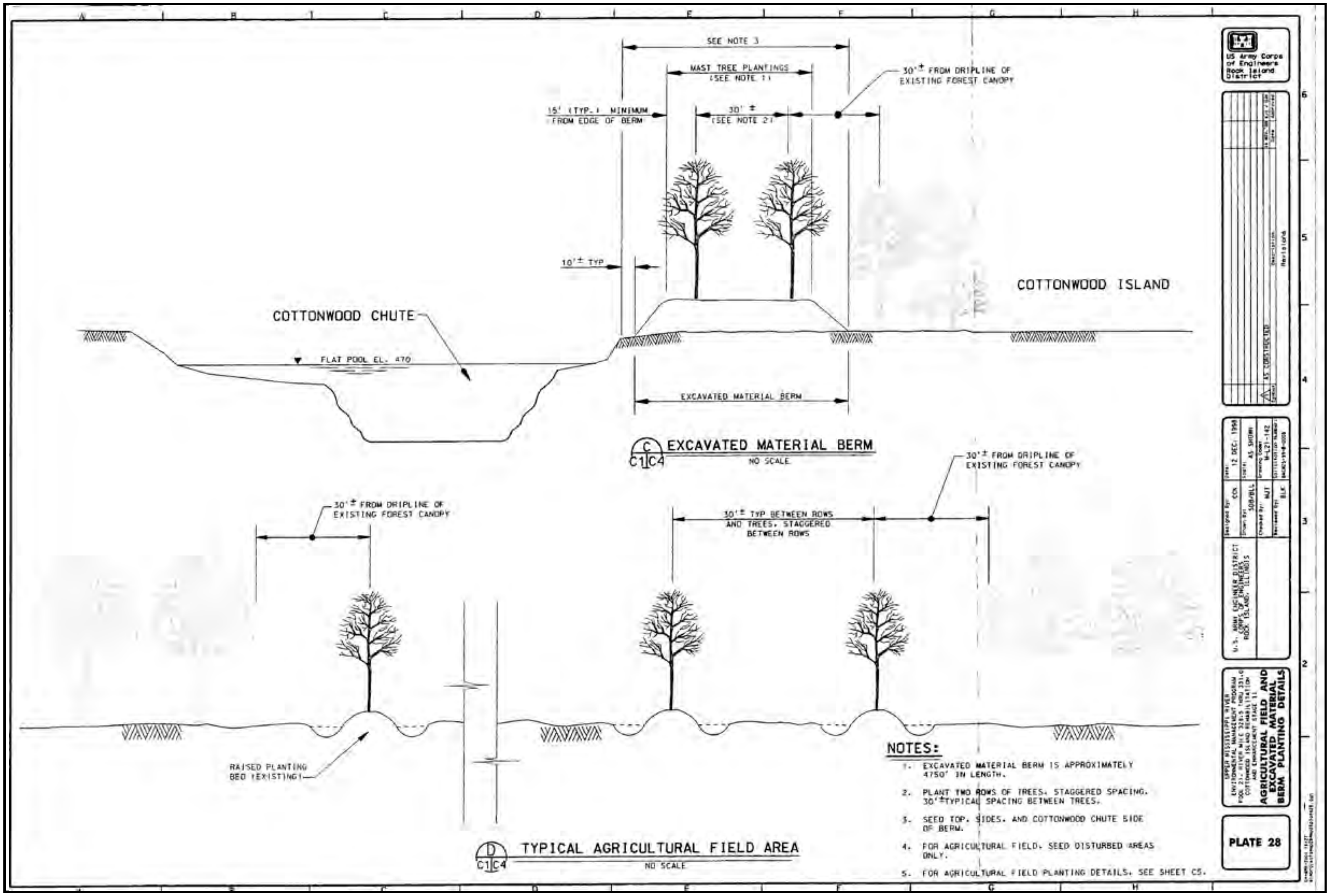
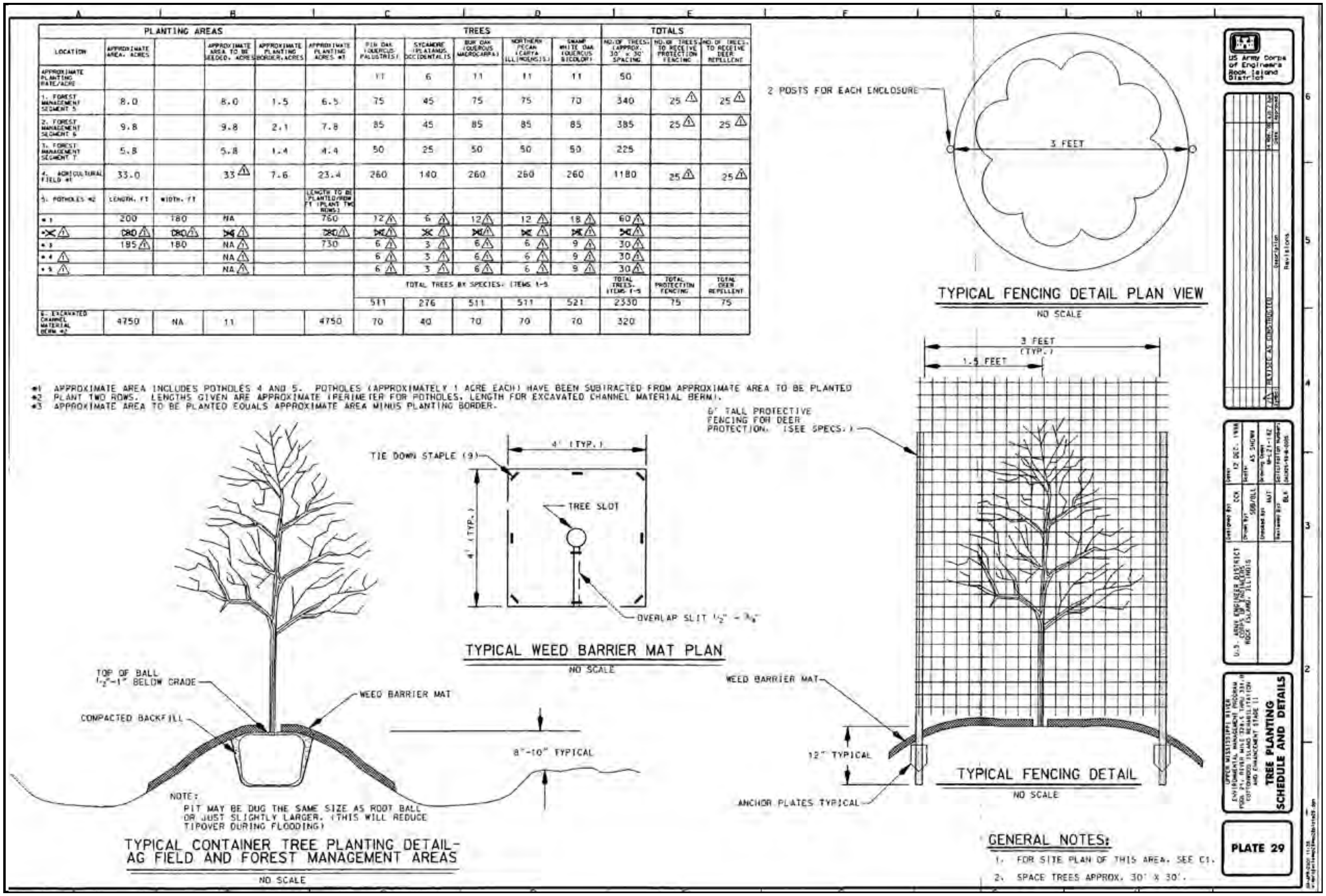


Figure 8-15. Forest Plans for Cottonwood Island



PLANTING AREAS						TREES					TOTALS		
LOCATION	APPROXIMATE AREA, ACRES		APPROXIMATE AREA TO BE SEEDED, ACRES	APPROXIMATE PLANTING BORDER, ACRES	APPROXIMATE PLANTING ACRES #1	PIN OAK (QUERCUS PALUSTRIS)	SYCAMORE (PLATANUS OCCIDENTALIS)	BUR OAK (QUERCUS MACROCARPA)	NORTHERN PECAN (CARYA ILLINOENSIS)	SWAMP WHITE OAK (QUERCUS BICOLOR)	NO. OF TREES (APPROX. 30' x 30' SPACING	NO. OF TREES TO RECEIVE PROTECTION FENCING	NO. OF TREES TO RECEIVE DEER REPELLENT
APPROXIMATE PLANTING RATE/ACRE						11	6	11	11	11	50		
1. FOREST MANAGEMENT SEGMENT 5	8.0		8.0	1.5	6.5	75	45	75	75	70	340	25 ⚠	25 ⚠
2. FOREST MANAGEMENT SEGMENT 6	9.8		9.8	2.1	7.8	85	45	85	85	85	385	25 ⚠	25 ⚠
3. FOREST MANAGEMENT SEGMENT 7	5.8		5.8	1.4	4.4	50	25	50	50	50	225		
4. AGRICULTURAL FIELD #1	33.0		33 ⚠	7.6	23.4	260	140	260	260	260	1180	25 ⚠	25 ⚠
5. POTHOLES #2	LENGTH, FT	WIDTH, FT			LENGTH TO BE PLANTED/ROW FT (PLANT TWO ROWS)								
#1	200	180	NA		760	12 ⚠	6 ⚠	12 ⚠	12 ⚠	18 ⚠	60 ⚠		
#2 ⚠	[illegible] ⚠	[illegible] ⚠	[illegible] ⚠		[illegible] ⚠	[illegible] ⚠	[illegible] ⚠	[illegible] ⚠	[illegible] ⚠	[illegible] ⚠	[illegible] ⚠		
#3	185 ⚠	180	NA ⚠		730	6 ⚠	3 ⚠	6 ⚠	6 ⚠	9 ⚠	30 ⚠		
#4 ⚠			NA ⚠			6 ⚠	3 ⚠	6 ⚠	6 ⚠	9 ⚠	30 ⚠		
#5 ⚠			NA ⚠			6 ⚠	3 ⚠	6 ⚠	6 ⚠	9 ⚠	30 ⚠		
						TOTAL TREES BY SPECIES (ITEMS 1-5)					TOTAL TREES (ITEMS 1-5	TOTAL PROTECTION FENCING	TOTAL DEER REPELLENT
						511	276	511	511	521	2330	75	75
6. EXCAVATED CHANNEL MATERIAL BERM #2	4750	NA	11		4750	70	40	70	70	70	320		

Figure 8-16. Forest Plans for Cottonwood Island

Better than 95 percent of the Mast trees planted in the Agricultural field have survived with most thriving. Some of the Sycamore trees planted in this area are over 20 feet tall with the trunks of some of the Oak trees over 8 inches in diameter. It is not known why the trees in this area are doing so much better than the others areas. It was noted that the trees were container grown when planted and the mats placed around the trees at the time of planting are present for nearly every tree in the Agricultural field. The additional size of the plantings and the removal of competition for nutrients and other benefits gained by the securely placed mats seem to have been of great benefit.

f. Ted Shanks Conservation Area HREP. Ted Shanks Conservation Area is located in Pool 24 between RMs 284 and 291 in the St. Louis District. Following the prolonged Mississippi River flood in 1993, much of the bottomland hardwood and floodplain forest at the site died and reed canary grass invaded these areas. Prior to the HREP project, Missouri Department of Conservation planted 300 acres of hard mast RPM® trees on higher elevations in 2002. However, in 2008, the exterior berm at the site was overtopped and the prolonged inundation killed over 80 percent of these trees. To restore the forest community at the site, the HREP will construct a setback levee and will plant approximately 300 acres of floodplain forest on lower elevations and 50 acres of hard mast trees on higher elevation. Construction for the project started in 2011. A monitoring plan which includes pre-construction (Fall 2011) and post-construction sampling will track tree survivability, tree height and basal diameter, and relative growth rate (USACE 2011).

g. Spring Lake Islands HREP. Spring Lake Islands is in lower Pool 5 between RMs 740 and 743.5 in the St. Paul District. As part of the EMP project the La Crescent Natural Resource Project office was asked to make planting recommendations for the proposed islands. It was decided that the best way to determine the suitability for mast-producing trees on these islands would be to sample various locations of existing mast-tree stands and determine at what elevation above average pool elevation these trees are most likely to be found. The results of this study show that swamp white oak occur on average at an elevation of 2.17 feet above average pool elevation. One black oak was found at an elevation of 3.01 feet. Elevations range from 0.57 to 3.17 feet above average pool elevation. Sample sites were selected with the initial expectation that water levels would be most controlled close to the dam and the most upstream sites would have a hydrology that most closely mimics the natural, free-flowing river. That data indicates that the distance from a dam may be an important consideration when designing a planting plan for an EMP project or when attempting to reforest an established island. In pools with mid-pool control points, proportionally even higher elevations above average pool elevation may be required upstream of the dam in order to support mast-producing trees. This could affect the design of the EMP projects where establishing mast-producing trees is an objective.

h. Huron Island Complex HREP. The Huron Island Complex is located in Pool 18 between RMs 421.2 and 425.4 in the Rock Island District. Due to the altered hydrologic regime after constructing Lock and Dam 18, about 99 percent of the Complex is located at or below the 2-year flood elevation. The forest now experiences prolonged water inundation (>50 days) during the growing season. The primary goal of the project which is currently in feasibility is to increase topographic diversity (Section C, page 8-3) through construction of elevated tiered berms (figure 8-17). Reforestation on the tiers will be accomplished through the planting of 15 mast tree species (i.e., river birch, bitternut hickory, northern pecan, shellbark hickory, common persimmon, honey locust, Kentucky coffeetree, black walnut, American sycamore, swamp white oak, bur oak, pin oak, American basswood, and overcup oak) in three RPM® sizes (i.e., #3, #5, and #15) to determine the efficiency and survival of planting larger trees (table 8-2). Tree monitoring is incorporated in the post-construction monitoring plan.

Table 8-2. Proposed Tree Planting at Varying RPM® -Sized Trees

Location	Planting Rate Per ½ Acre for Each of the 15 Species Planted
Plot 1	
RPM® #3	4
RPM® #5	0
RPM® #15	1
Plot 2	
RPM® #3	4
RPM® #5	2
RPM® #15	0
Plot 3	
RPM® #3	0
RPM® #5	2
RPM® #15	1

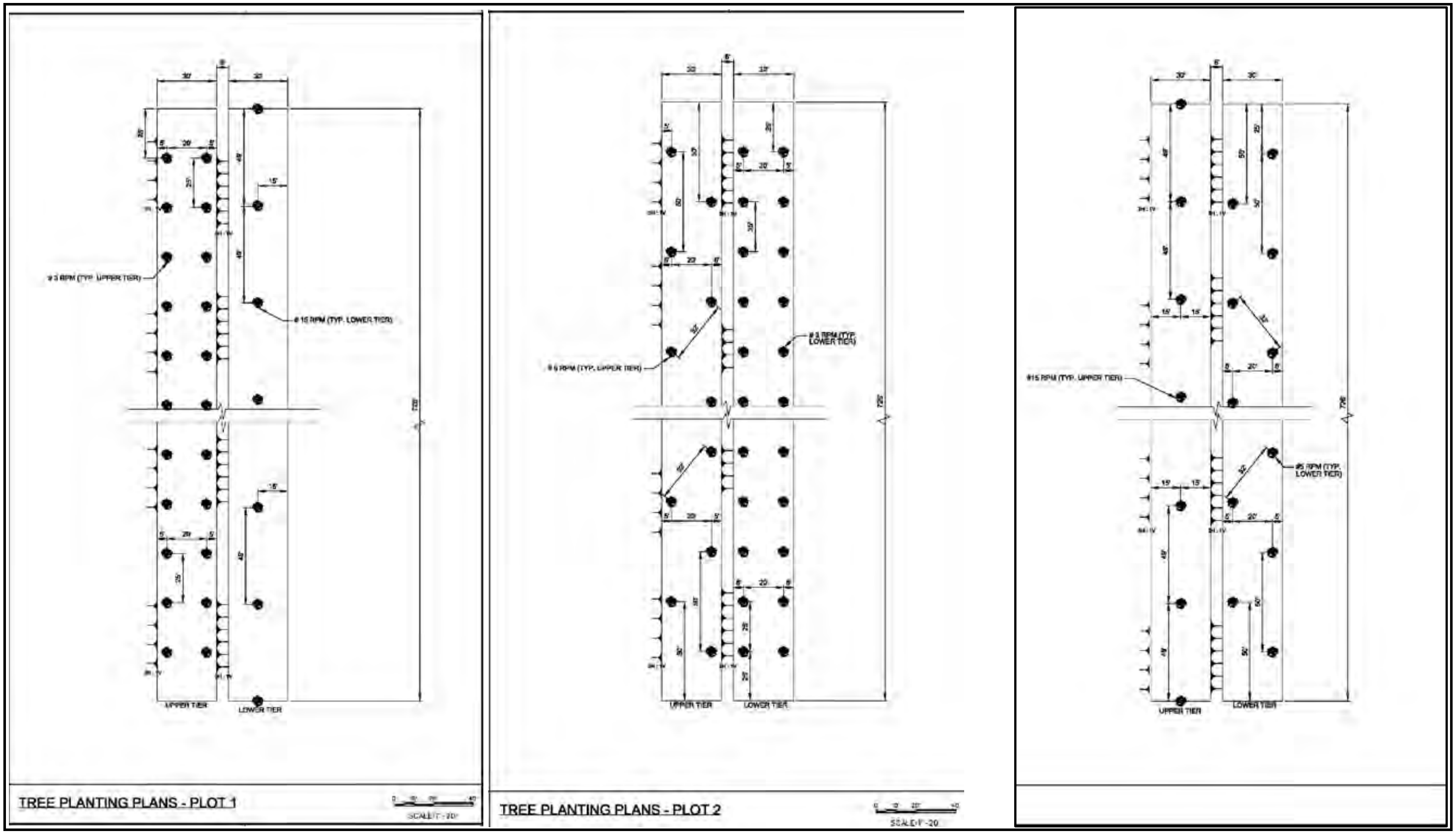


Figure 8-17. Proposed Tree Planting Plots for Huron Island

F. WETLAND SPECIES PLANTINGS (GRASSES, SEDGES, RUSHES, & FORBS)

Several wetland plant communities are dominated by herbaceous vegetation are comprised of grasses, sedges, rushes, and forbs. These wetland communities include wet prairie, sedge meadows, and fens. The UMR Basin contained extensive wet prairie along the river and on islands. The pre-settlement maps for portions of the UMRS indicate that the dominant plant community type on the floodplain was prairie (figure 8-18). These native plants provide habitat, cover, and food sources for wildlife and also help reduce site erosion and improve aesthetic appearance. However, much of these herbaceous wetland communities have been lost due to conversion to agriculture, urban development, fire suppression, and increased nutrients. Restoring native grasses, sedges, rushes, and forbs reestablishes these lost plant communities.

1. Design Methodology. Before restoring native plants into a site, it is important to ensure that the site conditions are what the plants need to grow and survive. Soil compaction, soil moisture, light availability, nutrient availability, and presence of invasive species need to be considered in order for successful establishment of a self-maintaining native plant community.

a. Seed Source. It is recommended to collect seeds within a one hundred-mile radius of the planting site, adapted to local weather conditions and flood frequency. This will also preserve the genetic integrity of the local population (IDNR 1997).

b. Seeding Rates. The seeding rates may vary according to the planting objectives (table 8-3). If a pure stand of grass is desired, then a seeding rate of 8 to 14 pounds pure live seed per acre should be sufficient depending on seedbed conditions (www.mdc.mo.gov). If a diverse mix of grasses and forbs are desired, then the amount of grass seed grass should be reduced to 2 to 4 pounds pure live seed per acre. Increase the amount of forb seeds until the mixture is 60 percent grass and 40 percent forbs by weight (Rock 1977). It is also possible to reduce the volume of grass by utilizing a process known as "debearding." In this procedure, the grass seeds are processed in a machine that removes the awns or "beards." The removal permits the seeds to pass through seeding devices more easily. If the seed has been debearded, then reduce the amount listed by one-fourth. The ratio of grass to forb seed will often be a matter of personal preference, seed availability, and cost.

Table 8-3. Seeding Rates for Native Warm-Season Grasses [1]

	Pounds of Pure Live Seed/Acre			
Grass species	**Good Seedbeds**	**Fair[2] Seedbeds**	**Savanna/Glade/ Prairie Mixture**	**Grassland Nesting Bird Mixture**
Big Bluestem	8.0	12.0	0.4	0
Indiangrass	7.8	11.7	0.4	0
Little Bluestem	6.4	7.8	2.8	2.6
Side-oats Grama	7.5	11.2	0	1.9
Eastern Gama Grass	8.0	12.0	1.0	1.0
Switchgrass (forage)	4.7	7.0	0	0.5
Switchgrass (levees, flood areas, erosion control)	7.0	14.0	0	0
Canada or Virginia wild rye	15.0	22.5	0.4	3.0
Native Prairie forbs	3.0	4.5	3.0	3.0

[1] Rates are pounds per Pure Live Seed (PLS)/acre. Available online at http://mdc.mo.gov/landwater-care/plant-management/native-plants/establishing-native-warm-season-grasses. Accessed 03 April 2012.
[2] Fair is for very coarse seedbeds or broadcast seeding

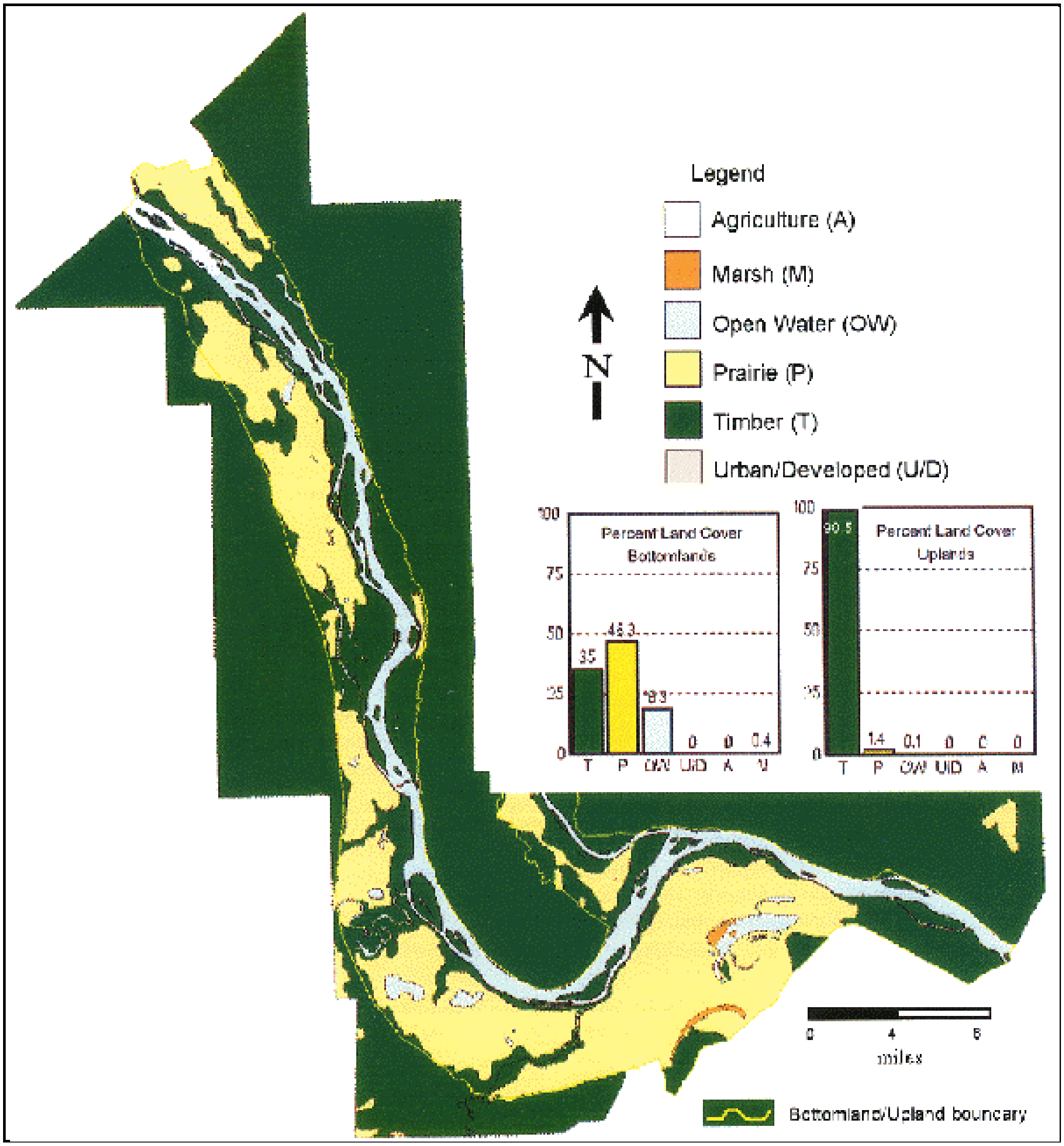


Figure 8-18. Geographic Information System Map Showing Pre-Settlement (1816) Land Cover Along Navigation Reaches 25 and 26 of the UMR. The graphs show percent land cover for timber, prairie, open water, urban/developed, agriculture, and marsh for the upland and bottomland regions (Nelson et al. 1998).

c. Planting Method. Seeds can be planted by a variety of methods, including drills, rotary spreaders, or hydraulic mulchers. Any large scale planting which does not drill the seed into the ground will require the use of a harrow to "set" the seed. The use of no till prairie seed drill has increased dramatically. Using no till planters reduces the cost, saves time, and prevents disruption of the soil that could be experienced with traditional methods of planting. If the conditions are suitable, and the seed viable, then germination should occur within 2 to 3 weeks post planting. Do not expect substantial growth of prairie plants one year post planting because during the first year the plants focus their energy on establishing their root systems. After two or three years, if survival is good, the plants should be well established.

d. Time of Planting. The ideal spring planting date varies with location and climate but generally includes a two-month period from April 15 to June 15, with the earliest planting being made in the southern reaches. Plantings made after the middle of June run the risk of encountering hot, dry weather which will reduce seed germination and seedling survival. It is also possible to plant during the late fall, thus allowing seeds to stratify naturally in the soil. If planting in the fall, be sure to plant late enough to allow seeds to germinate the following spring. The freezing temperatures could kill the seedlings if planted too early in the fall (IDNR 1997).

e. Plant Species. The key is to have a diverse mix of grasses, sedges, rushes, and forbs adapted to conditions of the project site. Several resources are available for selecting appropriate wetland species including the following resources:

- U.S. Department of Agriculture Natural Resources Conservation Services "Minnesota Wetland Restoration Plant Identification Guide Plant List" (available online: http://www.mn.nrcs.usda.gov/programs/wrp/plantid/plants.html; Accessed 09 May 2012).
- National Park Service "An introduction to using native plants in restoration projects" (http://www.nps.gov/plants/restore/pubs/intronatplant/intronatplant.pdf; Accessed 09 May 2012).

f. Invasive Plants. Invasive plants are a common problem in disturbed areas, including wetland restoration sites. Invasive plants need to be managed in order for successful establishment of native plants. The greater the amount of weeds that can be removed prior to native planting, the greater the chance the restoration site will succeed. Various removal techniques can be used depending on the invasive species. Typical methods for invasive plant removal include:

- physical removal (pulling, mowing, burning, tilling)
- smothering (mulching, cover crop)
- chemical control (pre- or post-emergent herbicides; Aqua Master ®)
- ecological control (flooding, fire, alter disturbance pattern, change nutrient availability, change soil pH, alter light availability)

g. Hydrology. When restoring wetland plant communities, restoring hydrology is critical. Many wetland plants are adapted to specific degrees of soil saturation, water depth, and flood frequency and duration. If the current hydrology of the site does not provide the conditions necessary for the desired plan species, it will need to be altered. Altering hydrology can be done through reshaping contours of the site with gently slopes or through reconnecting flow from a river or stream back through the wetland. For more intensive projects, water level management may be needed. See Chapter 5, *Localized Water Level Management*.

- Wetlands designed for waterfowl should be managed so that at least 50 percent of the surface area is less than 18 inches deep. This will enable emergent vegetation such as cattails to become established and grow vigorously. The other half of the wetland can range from 2 to 6 feet deep, but 3 to 4 feet of water is all that is necessary to assure water for duck broods.
- Where water quality improvement is the primary goal, water depths should be less than 3 feet with vegetation over 75 percent of the wetland.
- Water control structures can be used to periodically drain water off wetlands to enhance plant germination and otherwise manage wetland plants. The control structure can also be used to increase water depths to create open water areas.
- Slow drawdowns ultimately result in more food and habitat for waterfowl and shorebirds. The drawdowns must be timed carefully to avoid adversely affecting invertebrates and amphibians, however.

h. Role of Disturbance. The use of disturbance is important in managing herbaceous wetland communities. The use of fire can be useful in maintaining the native herbaceous plants while discouraging growth of invasive and woody plant encroachment. If fire is not a feasible method, mowing and raking the mulch off may be used to achieve a similar effect. If fire is used n conjunction with herbicide treatment to control invasive plants prior to planting, fire should follow the herbicide treatments to remove the large amounts of dead biomass .

i. Nutrients. Efforts should be made to reduce the exposure of the wetland plantings to nutrient-rich runoff. Certain invasive species, e.g., reed canary grass, are highly nutrient tolerant. The introduction of nutrient-rich runoff favors these invasive species and may reduce the likelihood of success in native wetland plantings.

j. Soils. Efforts should be made to select species that can survive with the soils found on the project site. If the soil cannot support the vegetation then the plantings will be most likely be unsuccessful. Consider making changes to the physical soil properties by increasing or decreasing saturated hydraulic connectivity by mechanical compaction or tillage, as appropriate; incorporate soil amendments; and consider the effects of construction equipment on soil density, infiltration, and structure. To change the soil bio-geochemical properties consider increasing the soil organic carbon by incorporating compost; or increasing or decreasing soil pH with lime, gypsum, or other compounds. (USDA 2010)

2. Lessons Learned

a. Soils

- A higher percentage of seeded species were dominant on sites with more than 1 foot of fine material (68 percent) than on sites with less fine material (56 percent).

- Fine material sites with more than 35 percent silt/clay had a higher average percent cover than sites with lesser amounts; however, at least 15 percent fines in the topsoil is sufficient to establish vegetation.
- Fine material increased the density of vegetation (both planted and naturally occurring).
- Six inches of fine material should be the minimum used for capping.
- The percent cover is highest on vegetation sites that were capped with more than 1 foot of fine material. A thicker cap of fine material with a higher percentage of fines may encourage a dense growth of woody and herbaceous cover.
- The fine material should contain sufficient coarse material to allow for aeration and water infiltration. This should be included in the specifications for the project.
- Fine material placement techniques that have worked successfully include: mechanical dredging in backwaters with placement using front-end loaders; hydraulic dredging in backwaters using containment cells for placement on the site and follow-up spreading and incorporation with heavy equipment; use of an irrigation sprayer to apply fine material dredged from a backwater using a small hydraulic dredge; and use of dump trucks to deliver topsoil where the project site is accessible by land.
- Ideally, fine material and soil amendments should be incorporated into the base material. Six inches of soil depth is often suitable for planting grass and forbs, with dry prairie species possibly requiring a bit less.
- Coarse, sandy dredged material is a poor medium for plant growth. It is important to incorporate some form of organic material with the sand to provide a suitable environment for seed germination, plant establishment and survival. To date, UMR revegetation projects have generally utilized fine sediments dredged from backwaters for topsoil. This has worked well. Sewage sludge and compost are other options being explored on a limited basis.
- To help promote long-term survival and health of vegetation plantings, project sponsors should be encouraged to monitor soil nutrient levels at reasonable intervals after the project is completed. Color and condition of foliage plus plant size may be used as an initial indicator. If a problem is suspected, a soil test will confirm the nutrient levels and can be arranged through local extension offices. Follow-up action may include application of fertilizer.
- Soil erosion can be very effectively controlled using vegetation. However, soil-holding capabilities vary between plant type and species. It is important to consult a vegetation specialist during the planning and design phase to help with plant selection.

b. Elevation

- Even within the floodplain, the flood tolerance of different plant species varies considerably. Elevation differences of 6 inches or less can determine whether a site will support certain types of plants. Therefore, it is very important to match plant species to elevations. A good general reference is Whitlow, T. H., and Harris, R. W. (1979). *Flood tolerance in Plants: A State-of-the-Art Review*, Technical Report E-78-

2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS., NTIS No. AD A075 938.

- Post-construction flooding on low elevation islands usually results in establishment of new plant species from seed that is washed onto the site. Sometimes this new vegetation can significantly change the original composition and density of plants, and often includes undesirable species, such as vetch, purple loosestrife, reed canary grass and others. Therefore, it is recommended that simple, relatively inexpensive planting mix be used on these lower areas.
- Islands have the potential to support diverse stands of vegetation that can then provide benefits such as wildlife habitat, visual barriers, and protection from wind. Vegetation types include bottomland forest, grassland, and shrubby woody vegetation. Designing islands with diverse topographic relief provides managers with a greater number of vegetative options.

c. Grass and Forbs

- Recommend using a diverse mix of native grass and forbs to ensure good overall survival. Wildflowers can enhance the appearance of the site.
- On projects where mulch is utilized, planners should consider weed-free certified mulch. The Minnesota Department of Transportation has such a program and vendors are listed on their website. By using this mulch, the risk of infesting your island with an invasive plant species is much reduced.
- Studies have shown that it is not necessary to plant any wetland plants in the wetland itself. Simply returning water to the area results in aquatic vegetation developing within 2 years.
- The aquatic plants that will likely grow include prairie cordgrass, arrowhead, cattails, sedges, marsh milkweed, water smartweed, and bulrushes (*Better Wetlands*).

3. Case Studies

a. Huron Island Complex HREP. Huron Island Complex is located in Pool 18 between RMs 421.2 to 425.4 in the Rock Island District. Due to the altered hydrologic regime after constructing Lock and Dam 18, about 99 percent of the Complex is located at or below the 2-year flood elevation. The forest now experiences prolonged water inundation (>50 days) during the growing season. The primary goal of the project which is currently in feasibility is to increase topographic diversity (Section C, page 8-3) through construction of elevated tiered berms. The design of the berm slopes incorporates the planting of a mix of wetland species transitioning from submerged to emergent aquatic vegetation to a mix of seasonally inundated emergent and scrub/shrub wetland species (table 8-4). The aquatic vegetation plantings will be accomplished through an experimental design incorporating planting at multiple elevations, utilizing exclosures, growth from the seed bank, and planting tubers, bareroot stock, and potted plants (figure 8-19). Comparisons between the planting treatments will determine optimal aquatic vegetation planting designs for future HREP projects

Table 8-4. Huron Island Complex Vegetative Planting Design

Permanently Inundated Aquatic Vegetation (EL. 426-529 ft) Seeding Rate = 500 total plants per ½ acre					
Plant Size	**Illinois Pondweed**	**Sago Pondweed**	**American Wild Celery**	**Coontail**	**American Elodea**
Potted plant	100	100	100	100	100
Bareroot	100	100	100	100	100
Root Tuber or Rhizome	100	100	100	100	100

Intermittently Exposed to Semi-Permanently Inundated Aquatic Bed (EL. 529 – 532 ft) Seeding Rate = 500 total plants per ½ acre				
Plant Size	**Waterwillow**	**Arrowhead**	**Pickerelweed**	**Smartweed**
Potted plant	125	125	125	125
Bareroot	125	125	125	125
Root Tuber or Rhizome	125	125	125	125

Seasonally Inundated Emergent Wetland (EL. 531 – 534 ft) Seeding Rate = 500 total plants per ½ acre				
Plant Size	**Sedges**	**Bulrush**	**Blue Flag Iris**	**Sweet Flag**
Potted plant	125	125	125	125
Bareroot	125	125	125	125
Root Tuber or Rhizome	125	125	125	125
Seed Mix (10 pounds per acre overall)[1]				

Seasonally Inundated Emergent Wetland (EL. 533 – 535 ft) Seeding Rate = 25 total trees per ½ acre					
Plant Size	**Hibiscus**	**Common Elderberry**	**Buttonbush**	**Dogwood**	**Sandbar Willow**
#3 RPM®	5	5	5	5	5

[1] Seed mix for tiers (under trees and scrub plantings) consists of Virginia wild rye, Canada wild rye, partridge pea, buttonbush, rice cut grass, cardinal flower, and sneezeweed

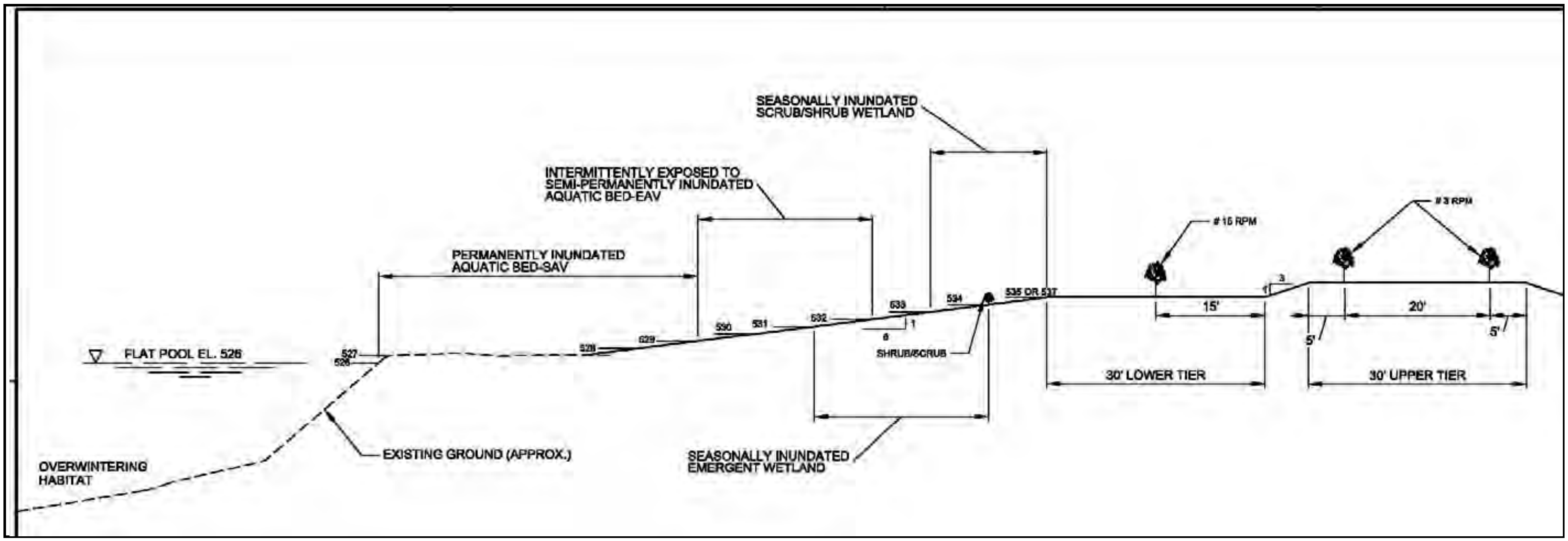


Figure 8-19. Proposed Plantings at Huron Island

b. Potters Marsh. Potters Marsh is located in Pool 13 between RMs 522.5 to 526.0 in the Rock Island District. One of the project features was to develop grassland on a confined placement site (CPS), with the objective of enhancing habitat for migratory birds by increasing feeding or resting areas by increasing suitability. Seven acres were designed for this feature.

The grassland area was constructed after initial settlement of dredged material. The area was seeded with selected grasses. This grassland area helped compensate for any lost vegetation due to the CPS construction and further enhanced the habitat values on the site. This grassland provides habitat for dabbling ducks as well as non-game species like the dickcissel and the indigo bunting. These improvements would provide an enhanced aesthetic environment for recreationists hunting or fishing within the complex boundaries.

The Refuge Manager reported that during the spring of 1997 several pairs of Canadian geese had nested in the interior of the CPS and mallards had nested on the associated berm and grassland areas. Small numbers of sandhill cranes visit the Savanna District each year. During 1995, a sandhill crane nest located near the containment site successfully hatched two young. This was the first documented sandhill crane nest in northwestern Illinois since 1872. Refuge staff observed nesting activity by sandhill cranes on or around the CPS grassland and berm in the spring of 1997, although actual nests or hatching success were not confirmed.

A third site visit to the CPS by Corps staff on October 2, 1997, showed cover crop rye grasses were still dominant on the berm and grassland. This third inspection revealed an increased presence of warm season grasses and forbs. Several species encountered, such as little bluestem, sideoats grama, and blue grama, were included in the seed mixture specified for the CPS. Other species, such as New England aster, Indian grass, and big bluestem, were not included in seeding specifications, but could either be natural components of the seed bank in the area or incidental inclusions in the seed mixtures applied after construction of the CPS.

During the October 2, 1997, site visit, Corps staff encountered a plant specimen tentatively identified in the field as the federally listed threatened species decurrent false aster (*Boltonia decurrens*). This identification was confirmed the following day by the endangered species coordinator at the Rock Island Field Office of the USFWS. The known range for this species in Illinois is limited to floodplains of the Illinois River and of the UMR downstream of the confluence with the Illinois. This species is not recorded as occurring in Carroll or Whiteside Counties, and the reason for its presence on the CPS feature at Potters Marsh is not known. There is a possibility that seeds of this species may have been accidentally transported to the site in seeding mixtures or through some other construction-related activity.

The initial vegetation response and observed waterfowl use of the area since construction indicates a positive response to the HREP and suggests that the project is providing benefits to migratory bird species. Establishment of a plant community dominated by warm season native grasses and forbs typically requires at least 3 to 4 years to fully develop, with periodic maintenance activity such as controlled burning to control less desirable vegetation (e.g., cottonwood seedlings). Continued monitoring of vegetation changes and migratory bird use within and around the CPS will help to determine the long-term performance of this feature.

On April 1, 1998, USFWS refuge staff conducted a maintenance bum of the berm and grassland areas of the CPS. Site visits conducted by Corps staff on May 22 and July 15, 1998, revealed an increased dominance of warm season grasses and forbs, as well as an increase in the number of species present. These initial observations suggest that the grassland community responded well to the initial maintenance bum.

Burning should be applied to the grassland and containment berm annually or biennially when possible. Mowing may also be beneficial where encroachment is initiating or when burning is not practicable.

The managed marsh continues to be submerged year round in order to control the encroachment of willow and cottonwood trees by keeping the marsh too wet for the trees to thrive. The project has been operated in this manner since June 2000. The strategy of flooding the marshland has been somewhat successful in killing undesirable vegetation, but encroachment remains a problem and would most likely worsen if the managed marshland were operated as a moist soil unit (moist soil units are drawn down in the summer months). Encroachment continues to be worse in the grassland area where the land is higher and flooding is not possible. Grassland and forb species were especially threatened by the encroachment.

The grasslands planted met the project objective of enhancing wildlife habitat.

c. West Newton Beneficial Use Site near Kellogg, MN. The scope of work for this project was to establish and maintain native prairie vegetation on 130.77 acres located near Kellogg, MN on lands owned by the Corps of Engineers, St. Paul District. Approximately 1.3 million cubic yards of dredged coarse-grained sands were hydraulically placed on the site to depths of up to 20 feet and then contoured to resemble sand dunes in 2002. The seed used for this project (tables 8-5, 8-6, and 8-7) was harvested from The Nature Conservancy lands within the Weaver Dunes complex just south of the project site. Seeding was conducted between May 1 and June 15, 2005. A cover crop of oats was planted during the 2004 growing season and crop residue remains at the site. Seed was drilled wherever possible, but inaccessible areas were broadcast seeded. The seeding density was defined as a minimum average of 70 plants per 100 square feet. Plant diversity was comprised of a minimum of 50 percent of grass species and 25 percent of forb species. Mowing was used to control pioneering non-native plant species during the first growing season (before the general height is 12 inches or when the non-native begin to flower, whichever is earlier). Mowing occurred before the non-native set seed. Mowing was set at a height of 4 inches.

Table 8-5. Species, Seed Rates, and Acres Planted at West Newton Beneficial Use Site

Common Name	Scientific Name	Seeding Rate (ounces per acre) Mix 1	Seeding Rate (ounces per acre) Mix 2	Acres To Be Planted On (Mix 1)	Acres To Be Planted On (Mix 2)
little bluestem	*Andropogon scoparius*	32	32	110.33	20.44
sand dropseed	*Sporobolus cryptandrus*	0.5	0.5	110.33	20.44
big bluestem	*Andropogon gerardii*	8	8	110.33	20.44
hoary vervain	*Verbena stricta*	1	1	110.33	20.44
dotted mint	*Monarda punctata*	1	0	110.33	0
common evening primrose	*Oenthera biennis*	0.5	2	110.33	20.44
Canadian milk vetch	*Astragalus canadensis*	0.25	0	110.33	0
silky prairie clover	*Petalostemum villosum*	1.8	0	110.33	0
purple prairie clover	*Petalostemum purpureum*	1	1	110.33	20.44
white prairie clover	*Petalostemum candidum*	1	0	110.33	0
round headed bush clover	*Lespedeza capitata*	2	2	110.33	20.44
lead plant	*Amorpha canescens*	.5	0	110.33	0
showy sunflower	*Helianthus pauciflorus*	.25	0	110.33	0

Table 8-6. Seed Mix 1 Used at West Newton Beneficial Use Site [1]

Forbs	**% by Weight**
Anemone cylindrical (Thimbleweed)	0.07
Anemone patens wolfgangiana (Pasque Flower)	0.17
Artemisia caudata (Beach Wormwood)	0.17
*Artemisia ludoviciana (*Prairie Sage)	0.07
Asclepias tuberosa (Butterfly Weed)	1.33
Asclepias verticillata (Whorled Milkweed)	0.33
Aster azureus (Sky Blue Aster)	0.17
Astragalus canadensis (Canadian Milk Vetch) __ Scarify	0.17
Baptisia leucantha (White Wild Indigo) __ Scarify	1.33
Campanula rotundifolia (Harebell)	0.07
Cassia fasciculata (Partridge Pea) __ Scarify	21.28
Coreopsis palmata (Prairie Coreopsis)	0.33
Crotalaria sagittalis (Rattlebox)	0.67
Desmodium illinoense (Illinois Tick Trefoil)	0.67
Euphorbia corollata (Flowering Spurge)	0.67
Gnaphalium obtusifolium (Sweet Everlasting)	0.13
Helianthus pauciflorus (Showy Sunflower)	0.17
Helianthus occidentalis (Western Sunflower)	0.17
Kuhnia eupatorioides (False Boneset)	0.17
Lespedeza capitata (Round-headed Bush Clover)	1.33
Liatris aspera (Button Blazing Star)	0.67
Monarda fistulosa (Wild Bergamot)	0.67
Monarda punctata (Spotted Bee Balm)	0.67
*Oenthera biennis (*Evening Primrose)	0.34
Petalostemum candidum (White Prairie Clover)	0.67
*Petalostemum purpureum (*Purple Prairie Clover)	0.67
Petalostemum villosum (Silky Prairie Clover)	1.20
Potentilla arguta (Prairie Cinquefoil)	0.17
Ratibida pinnata (Yellow Coneflower)	0.67
Rudbeckia hirta (Black-eyed Susan)	0.67
Sisyrinchium campestre (Prairie Blue-eyed Grass)	0.07
Solidago nemoralis (Old Field Goldenrod)	0.07
Solidago rigida (Stiff Goldenrod)	0.17
Verbena stricta (Hoary Vervain)	0.67
Trees, Shrubs & Vines	
Amorpha canescens (Lead Plant)	0.33
Ceanothus ovatus (Red Root) __ Scarify	0.07
Rosa arkansana (Prairie Wild Rose) __ Scarify	0.33
Grasses, Sedges & Rushes	
Andropogon gerardii (Big Bluestem PLS)	5.32
Andropogon scoparius (Little Bluestem PLS)	21.28
Bouteloua curtipendula (Side-oats Grama PLS)	21.28
Carex brevior (Plains Oval Sedge)	0.33
Carex muhlenbergii (Sand Bracted Sedge)	0.67
Elymus canadensis (Canada Wild Rye PLS)	5.32
Koeleria cristata (June Grass)	1.33
*Panicum virgatum (*Switch Grass PLS)	1.33
Sorghastrum nutans (Indian Grass PLS)	5.32
Sporobolus cryptandrus (Sand Dropseed)	0.33

[1] PLS - Pure Live Seed

Table 8-7. Seed Mix 2 Used at West Newton Beneficial Use Site

Forbs	**Grams**
Cassia fasciculata (Partridge Pea) __ Scarify	453.7600
Lespedeza capitata (Round-headed Bush Clover)	56.7200
Liatris aspera (Button Blazing Star)	28.3600
Oenthera biennis (Evening Primrose)	56.7200
Petalostemum purpureum (Purple Prairie	28.3600
Ratibida pinnata (Yellow Coneflower)	28.3600
Rudbeckia hirta (Black-eyed Susan)	28.3600
Verbena stricta (Hoary Vervain)	28.3600
Grasses	
Andropogon gerardii (Big Bluestem PLS)	226.8800
Andropogon scoparius (Little Bluestem PLS)	907.5200
Bouteloua curtipendula (Side-oats Grama PLS)	907.5200
Elymus canadensis (Canada Wild Rye PLS)	226.8800
Koeleria cristata (June Grass)	56.7200
Panicum virgatum (Switch Grass PLS)	56.7200
Sorghastrum nutans (Indian Grass PLS)	226.8800
Sporobolus cryptandrus (Sand Dropseed)	14.1748

d. Lock & Dam 4 Embankment. The scope of work for this project was to establish trees, shrubs, grass, and forbs vegetation adjacent to Lock and Dam 4 near Alma, WI in the St. Paul District. The project area is approximately 7.5 acres in size and is located on the upstream side of the Mississippi River Lock and Dam 4 embankment, owned by the Corps. The embankment was originally constructed in the 1930s. The purpose of the plantings as well as the offshore berm is to provide protection of the Lock and Dam embankment from erosive wind and wave energy. The berm features four terraces of varying elevation and a woody clear zone that corresponds to the underlying footprint of the embankment. The berm was constructed from coarse-grained sands dredged from the navigation channel of the Mississippi River. The planting plan included five different forest or grass/forbs species combinations based on site elevations or a woody-clear zone over the footprint of the existing embankment. Willow cuttings were planted along the shoreline (667 feet) to 668.5 feet (6 rows total) the entire length of the berm. The hardwood slope section (668.5 to 670.5 feet) included bare root seedlings of cottonwood, silver maple and river birch. The hardwood terrace section (670.5 to 673 feet) included bare root seedlings of moderate flood tolerant species (swamp white oak and hackberry). The hardmast terrace section (above 673 feet) included bare root seedlings of bur oak and black walnut. The “clear zone” was planted with a mix of native grass and forb seed.

The mix (table 8-8) used helps maintain a woody plant-free zone along and just adjacent to the upstream footprint of the existing LD4 embankment. The seeding density was 81 seeds per foot. Plant diversity was comprised of 45 percent grasses, 50 percent cover crops and 5 percent forbs.

Table 8-8. Grass and Forb Mix Used at the Lock and Dam 4 Embankment Project

Grasses	**% of Mix**
Avena sativa (oats)	40
Bouteloua curtipendula (Sideoats grama)	10.00
Bouteloua gracilis (Blue grama)	10.00
Bromus kalmii (Kalm's brome)	5.00
Elymus canadensis (Canadian wild rye)	8.00
Koeleria macrantha (June grass)	2.00
Lolium italicum (Annual Rye grass)	10.00
Schizachyrium scoparium (Little bluestem)	10.00
Forbs	
Aster laevis (Smooth blue aster)	0.10
Astragalus Canadensis (Canada milkvetch)	0.70
Dalea canadida (White prairie clover)	0.60
Dalea purpurea (Purple prairie clover)	0.60
Liatris aspera (Rough blazingstar)	0.60
Penstemon grandiflorum (Showy penstemon)	0.70
Ratibida columnifera (Columnar coneflower)	0.60
Rudbeckia hirta (Black-eyed Susan)	0.30
Solidago rigida (Stiff goldenrod)	0.60
Verbena stricta (Hoary vervain)	0.20

e. Banner Marsh HREP. Banner Marsh is located in the LaGrange Pool on the Illinois Waterway between RMs 138.0 and 144.0 in the Rock Island District. One goal of the project was to enhance terrestrial habitat to increase food and cover for terrestrial birds and mammals by planting native warm season grasses (USACE 2002b). In May 2003, a mix of warm season grasses were planted with the following planting rates per acre:

Species	**Pounds/Acre**
Big bluestem (*Andropogon gerardii*)	3
Little bluestem (*Schizachyrium scoparium*)	3
Indian grass (*Sorghastrum nutans*)	2
Perennial rye grass (*Lolium perenne*)	20
Sideoats gramma (*Bouteloua curtipendula*)	2

All seeding took place at higher elevations (above 439.0). As of 2004, no inspection or monitoring of terrestrial habitat have been performed. The site manager reported prairie seeding of the borrow areas have been successful (USACE 2004b).

f. Spring Lake HREP. Spring Lake Islands are located in lower Pool 5 in the St. Paul District. The Spring Lake EMP PDT designed two grassland seed mixes in 2004 for use on islands as shown in the following two tables (tables 8-9 and 8-10). For sections of islands where vegetative management will be minimal, the abbreviated prairie mix should provide a relatively quick cover of native species. On higher sections (4 feet above average pool), the diverse prairie mix is recommended. Planners should be advised that active management is required to maintain grassland on the river, to include mowing during establishment of the stand and periodic controlled burns later to control invasive species and woody vegetation. In addition to providing habitat benefits, native prairie grasses form deep, dense root systems that will ultimately provide more protection to the islands.

Table 8-9. Abbreviated Prairie Mix Used at Spring Lake

Common Name	Scientific Name	Seeding Rate (ounces per acre)
Virginia wild rye	*Elymus virginicus*	48
Canada wild rye	*Elymus canadensis*	48
Switchgrass	*Panicum virgatum*	32
Indiangrass	*Sorghastrum nutans*	16
Prairie cordgrass	*Spartina pectinata*	3
Black-eyed Susan	*Rudbeckia hirta*	2

Table 8-10. Diverse Prairie Mix Used at Spring Lake

Common Name	Scientific Name	Seeding Rate (ounces per acre)
Big bluestem	*Andropogon gerardii*	25.5
Little bluestem	*Andropogon scoparius*	25.5
Sideoats grama	*Bouteloua curtipendula*	25.5
Rough dropseed	*Sporobolus compositus*	1
Virginia wild rye	*Elymus virginicus*	25.5
Canada wild rye	*Elymus canadensis*	25.5
Switchgrass	*Panicum virgatum*	4
Indiangrass	*Sorghastrum nutans*	25.5
Prairie cordgrass	*Spartina pectinata*	2
Black-eyed susan	*Rudbeckia hirta*	3
Evening primrose	*Oenthera biennis*	2
Purple prairie	*Dalea purpurea*	3
Brown-eyed	*Rudbeckia triloba*	2
Yellow	*Ratibida pinnata*	2
Bergamot	*Monarda fistulosa*	1
Blue vervain	*Verbena hastate*	1.5
Hoary vervain	*Verbena stricta*	1.5
Sky blue aster	*Aster oolentangiensis*	0.5
Frost aster	*Aster pilosus*	0.5
Showy sunflower	*Helianthus laetiflorus*	0.5

G. LEVEE SETBACKS

Within the UMR System, an extensive levee system isolates the floodplain from the mainstem river. The levees reduced flooding and opened the floodplain to rural, industrial, and residential development. Historic maps illustrate the ancient courses of the Mississippi River, which showed a wider meandering channel compared to the currently confined river channel (figures 8-20a and 20b). Levee placement not only straightened the channel, but also substantially altered the form and function of the Mississippi River. Detachment of the floodplains from the main stem river system has resulted in the loss of channel complexity (meanders, sand bars) and floodplain process and function (flood water and sediment storage, riparian and wetland development). These changed conditions greatly reduced off-channel aquatic and riparian habitat for both fish and wildlife by reducing available food sources, cover, and water resources.

Figure 8-20a. Historic Course of Mississippi River Meander Belt Near Cape Girardeau, MO

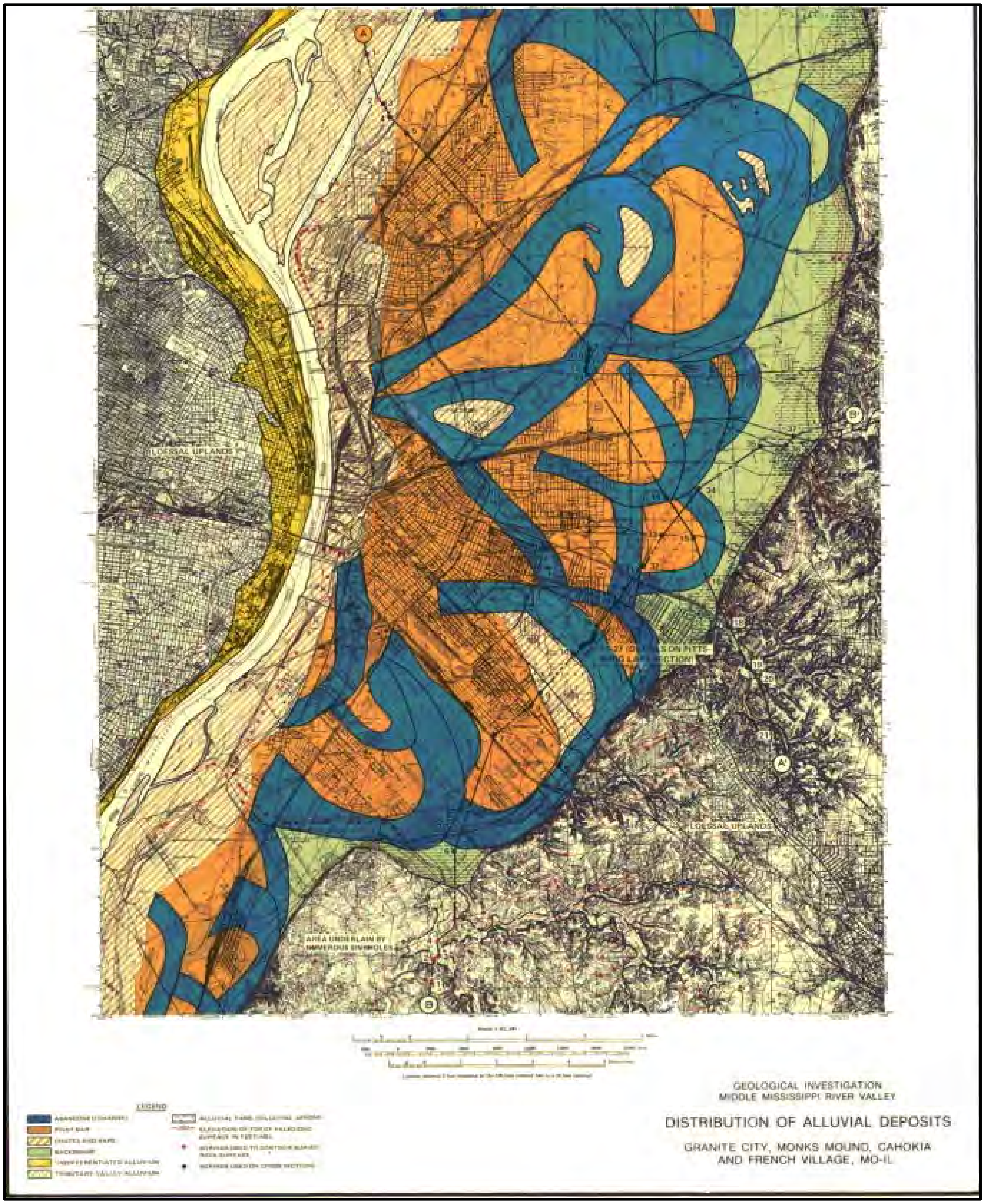


Figure 8-20b. Historic Course of Mississippi River Meander Belt Near St. Louis, MO

The use of setbacks within the Corps of Engineers is a relatively new tool to restore connectivity between the floodplain and the main stem river. A setback levee has been defined as "an earthen embankment placed some distance landward of the bank of a river, stream, or creek. It develops bypasses for the mainstream, flooding a land area usually dry but subject to flooding at high mainstream stages" (USACE 1999b). Setback levees allow the streamflow to spread and slow by creating a wider, connected floodplain with increased conveyance capacity of the floodway. They provide floodplain storage benefits and sustain dynamics of the river system, which depends on recurring flood events. The passage of water and sediment in the channel, and their exchange between the channel and the floodplain, characterizes the physical environment and effects of habitat, biodiversity, and sustainability of the river (Poff et al. 1997). Setback levees would also permit an active natural meander belt on rivers that do not need to be maintained for navigation, thereby improving the floodplain habitat.

1. Design Methodology. Design and construction of setback levees should consult the design guidelines outlined in EM 1110-2-1913 (30 April 2000). A basic levee design cross section is depicted in figure 8-21. The EM is tailored to levees protecting life and property, which are designed to perform at higher flood stages. Less conservative designs (i.e., levee height) are permissible for EMP and other ecosystem restoration projects, but the overall methods of levee construction are the same. Typical earthwork specifications for a Rock Island District levee are as follows:

- Grading tolerance: 0 to +4 inches for clay, 0 to + 6 inches for sand
- Benches: 1 to 3 feet vertical face max
- Fill lift thickness: 8 inches loose
- Compaction
    - Compacted Clay: 95 percent of standard Proctor (ASTM D698)
    - Semi-compacted clay: 90 percent of ASTM D698
    - Sand Levee: 80 percent relative density (ASTM D4253/D4254)
    - One test per left per day or every 3,000 cubic yards
    - Standard proctor or relative density for each soil type or every 10,000 cubic yards
- Moisture Content
    - Field test with microwave oven (ASTM D4643) at Contractor's discretion
    - Lab verify ALL test (ASTM D2216) for each compaction test
- Soil Classification
    - Grain size analysis (ASTM D422) for each Proctor test
    - Atterberg limits (ASTM D4318) for each Proctor test

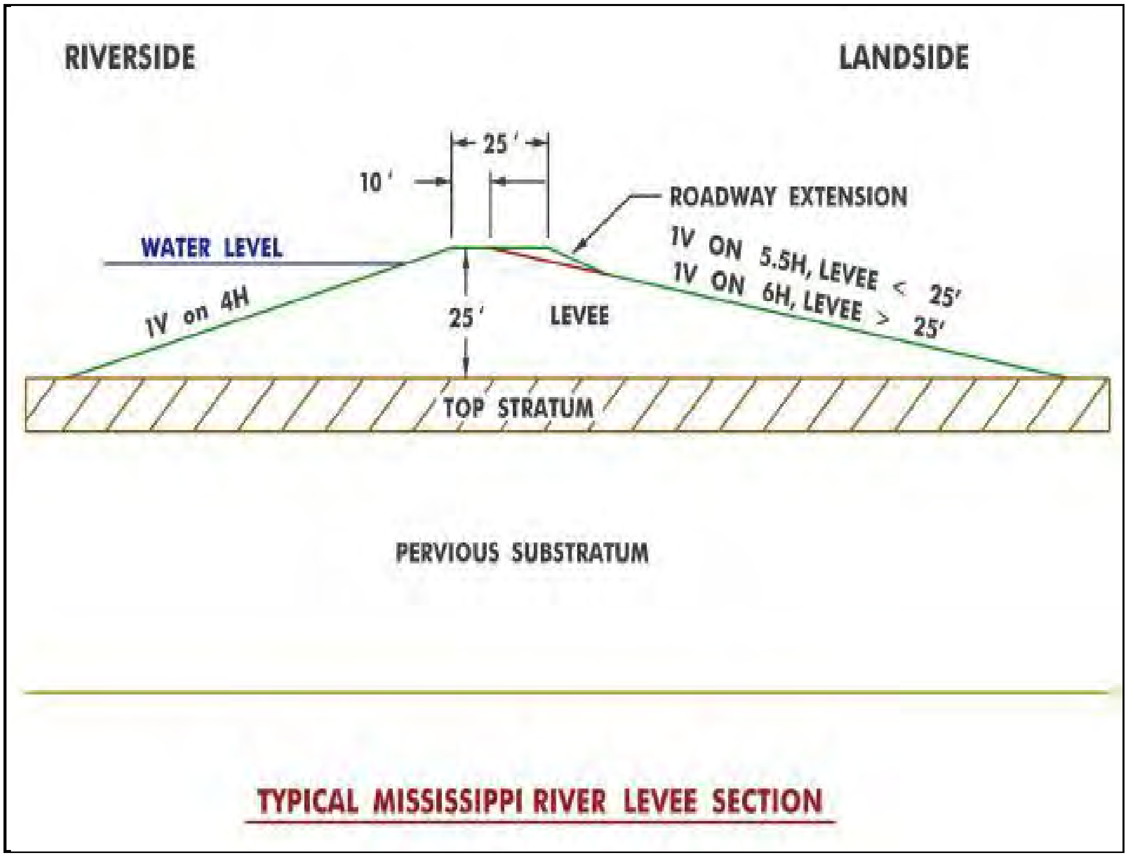


Figure 8-21. Generic Levee Cross-Section for a Sand Levee

2. Lessons Learned. The following statements are hypotheses, rather than facts, since most of the projects that have used levee setbacks are early in planning or construction, with no data on post-construction effects. Further monitoring and evaluation of levee setbacks will be needed to have definitive lessons learned for this restoration technique.

- Setback levees restore ecosystem function such as sediment recharge and nutrient reduction.
- Environmental benefits increase with width of setback (inter-levee distance).
- A spillway along the setback may be needed to reduce scour during overtopping flood events.
- The height of setback levee is based on project goals and objectives.
- Setback levees can be constructed landward of an existing riverside levee. The existing riverside levee can be degraded on the downstream end to allow back-flooding into the setback area. The remainder of the riverside berm can stay intact to act as a sediment deflection barrier during high flood events and provide areas of higher elevation for hard mast tree plantings (if levee maintenance allows this).

- Pre- and post-construction monitoring of biological and physical parameters should be incorporated into the study design to assess setback benefits.
- In terms of general levee design and construction lessons learned, use a multi-disciplinary team and follow these design steps:

1) Perform geologic survey to identify potential hazards (i.e., shallow bedrock, old sloughs) and conduct preliminary subsurface exploration
2) Analyze preliminary data, establish preliminary profiles, borrow locations, and embankment sections
    - Clay embankment: 1V:3H side slopes with 10 foot crown width
    - Sand Levee: 1V:4H river side slope with 1V:5H land side slope with 10 foot crown width. 10H base width or add berm for through seepage.
3) Final exploration to refine stratigraphy, measure shear strengths, and refine borrow material limits
    - Subsurface exploration and testing: 200 ft to 1,000 ft "boring" spacing (disturbed and undisturbed samples, vane shear testing, cone penetration testing); test pits and trenches; piezometers; pump testing
4) Define stratigraphy and design parameters; calculate rough quantities.
5) Divide project into design reaches based on geometry, stratigraphy, and design parameters, etc.
6) Analysis of underseepage and through-seepage (blanket theory, lane's weighted creep ratio, finite element methods); slope stability (deterministic analyses, Spencer's Method); settlement (Bousseniesq Stress Distribution); trafficability of levee surface
7) Design for "problem area" (seepage, stability, settlement, trafficability, non-geotechnical)
8) Establish final sections for each reach
9) Compute final quantities, determine final borrow locations
10) Design slope protection (erosion resistance, resiliency, levee safety)

Design *continues* through construction http://www.ucs.iastate.edu/mnet/repository/2012 /geotechnical/presentations/levee.pdf; Accessed on 28August 2012)

3. Case Studies

a. Sacramento River, California. Setback levees have been investigated by the Corps' Sacramento District for the Sacramento River. The Hamilton City Flood Damage Reduction and Ecosystem Restoration is slated to begin summer 2012 (RM 192 to 202), the project focuses on measures that produce both flood risk reduction and ecosystem restoration benefits. The multi-benefit project consists of constructing a setback levee about 6.8 miles long that would have varying heights (7.5 feet to 3 feet) and consequently, varying levels of performance for flood damage reduction while reconnecting approximately 1,500 acres of floodplain (USACE 2004c). The existing degraded levee is privately owned and mostly made of earthen material susceptible to erosion. The goal of the setback levee is increase capacity of the Sacramento River, decrease river velocities, and ease pressure from periodic flooding by allowing 1,500 acres of floodplain to be reconnected to the river.

Another study was performed to evaluate setback levees on the Sacramento River (RM 84 to 143). A preliminary analysis was performed to determine the effect the setback would have along the Sacramento River. This was done using a three-scenario strategy for setback inter-levee width of 3000 feet, 6000 feet, and 9000 feet. Each scenario was analyzed in terms of hydrology, ecology, and economics. The floodplain inundation depth and the change in channel velocity were determined for each scenario at several cross sections using a number of standard flood recurrence intervals. The analysis of the three scenarios indicates that benefits increase with increased inter-levee distance, and the 9000 foot setback scenario was found to provide the greatest benefits. For the aquatic ecosystem, this scenario establishes the most desirable conditions for improving habitat because channel velocity is decreased and there is great potential for backwater habitat formation. In terms of terrestrial ecosystem, the area of willow, cottonwood, and mixed riparian communicates is maximized under this scenario. It also allows the most freedom for channel migration to occur over time. Additionally, the economic analysis also shows this scenario to be the most attractive (Accessed 06March2012 http://www.bren.ucsb.edu/research/2000Group_Projects/Levees/levees_final.pdf).

b. Ted Shanks Conservation Area HREP. This HREP is located in Pool 24, Mississippi River, RMs 286 to 293 in the St, Louis District. At the Ted Shanks Conservation Area, the height of the proposed setback would match the height of the existing exterior berm. The crown width was designed to be 12 feet, and side slopes 1 vertical on 3 horizontal. The bottom width would be approximately 75 feet and construction limits would be approximately 125 feet for the length of the setback. Clearing and grubbing would be required within the berm footprint and recommended within 15 feet of the proposed setback toe. A 1,000-foot segment of the existing exterior berm would be degraded. Degrade location was chosen to avoid impacts to high-quality forest and promote water backing up into the floodplain. Degrading the exterior berm would create a hydrologic connection between riverward lands of setback and the river. The setback and berm degrade should prevent flood waters from ponding on the forest in this area, and provide fish access to inundated floodplain for spawning and rearing.

The bottomland hardwood and floodplain forests within the project site have been degraded due to the elevated water table, prolonged inundation from overtopping floods, and invasion by reed canary grass. The undersized water control structures lack the ability to quickly drain the area; a major contributor to the tree death and degraded wetland habitat. The project features include setback levees in two areas of the existing exterior levee along with a partial exterior levee degrade to allow for back flooding into the areas. Other project features include constructing new water control structures to increase water drainage capacity, constructing interior berms to improve water and vegetation management, reforestation, constructing rock riffles and hard points within a slough, and a new pump station (USACE 2011). The project started construction in fall of 2011. Pre-construction monitoring for trees in the two setback locations was collected in fall of 2011. Post-construction monitoring is planned to assess the benefits of the setback in the future.

c. Clarence Cannon National Wildlife Refuge HREP. This HREP is located in Pool 25, Mississippi River, RMs 263.5 to 260.6 in the St. Louis District. The main resource problems at the project site is loss of native vegetation, limited ability to mimic historic flow regimes, habitat fragmentation, and lack of connectivity with the Mississippi River. The proposed project features include setback levee (with a spillway) with partial exterior berm degrade to allow for back flooding of the area, removal/modification of interior berms, pump station, dredging of sloughs and historic meanders, and native plantings. This project is currently in feasibility. Fish and water quality monitoring was conducted in May of 2011 within the proposed setback area. Post-construction monitoring is planned to assess benefits of the setback in the future.

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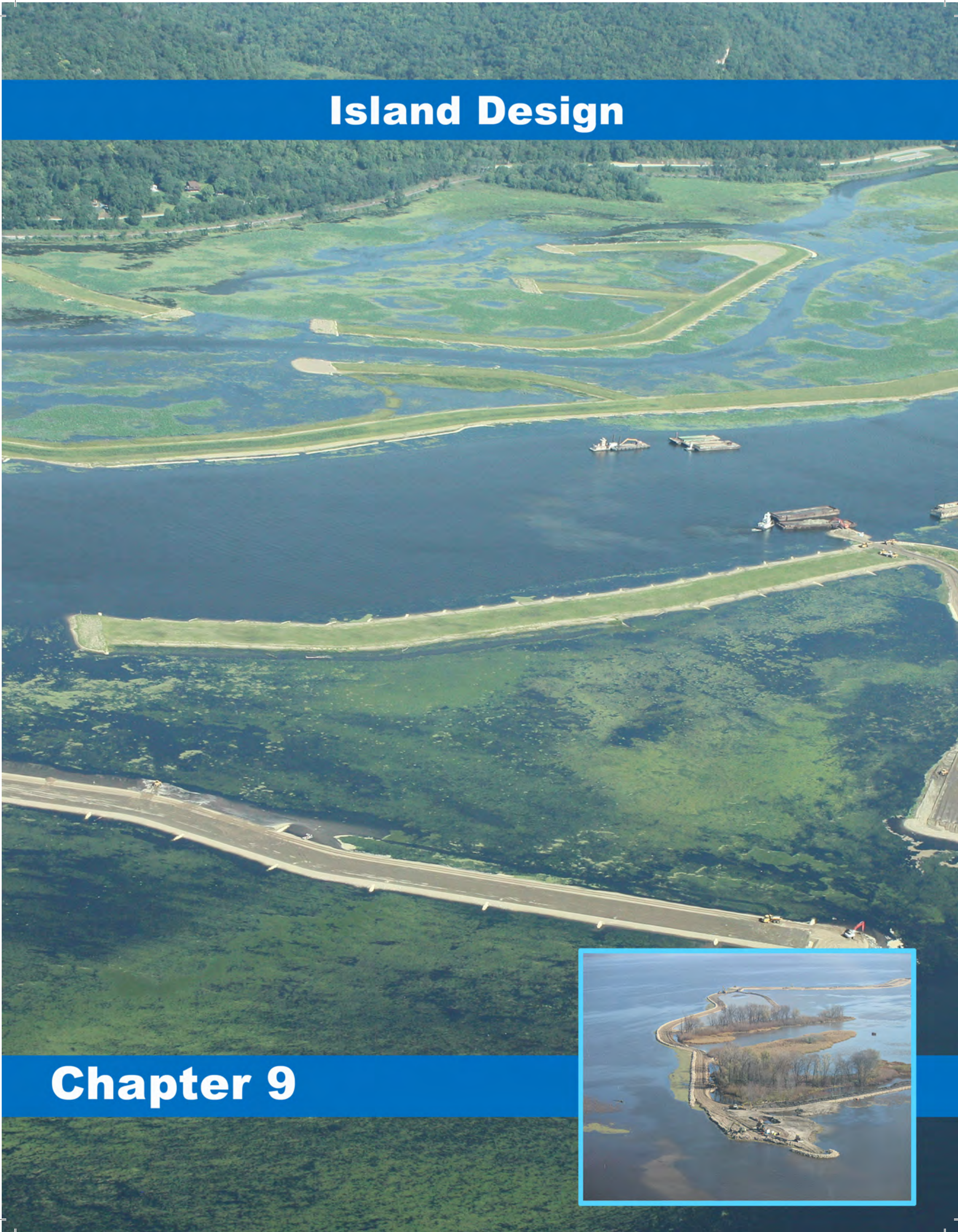
Island Design



Chapter 9

UPPER MISSISSIPPI RIVER RESTORATION ENVIRONMENTAL MANAGEMENT PROGRAM ENVIRONMENTAL DESIGN HANDBOOK

CHAPTER 9

ISLAND DESIGN

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CHAPTER 9

ISLAND DESIGN

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ISLAND DESIGN

A. RESOURCE PROBLEMS AND OPPORTUNITIES

The Upper Mississippi River System (UMRS) has been altered by drivers such as lock and dam construction, conversion of the watershed to agriculture, tributary channelization, floodplain isolation due to agricultural levees, urbanization in some reaches, invasive species, and climate change. The affects of these stressors on the condition of the ecosystem varies depending on location in the river. Lock and dam construction had the greatest effect in the lower half of each navigation pool where the floodplain was inundated by the increased water surface elevation. Inundation caused an immediate change in the land-water distribution followed by a long-term change that included the gradual loss of land (figure 9-1). The 1890 map represents the pre-inundation condition; the 1939 map is the immediate post lock and dam condition only 2 years after Lock and Dam 8 went into operation; and the 1989 map shows the land water distribution after 52 years of inundation and represents the conditions in lower Pool 8 at the beginning of the UMRR-EMP, when the loss of islands was very clear.

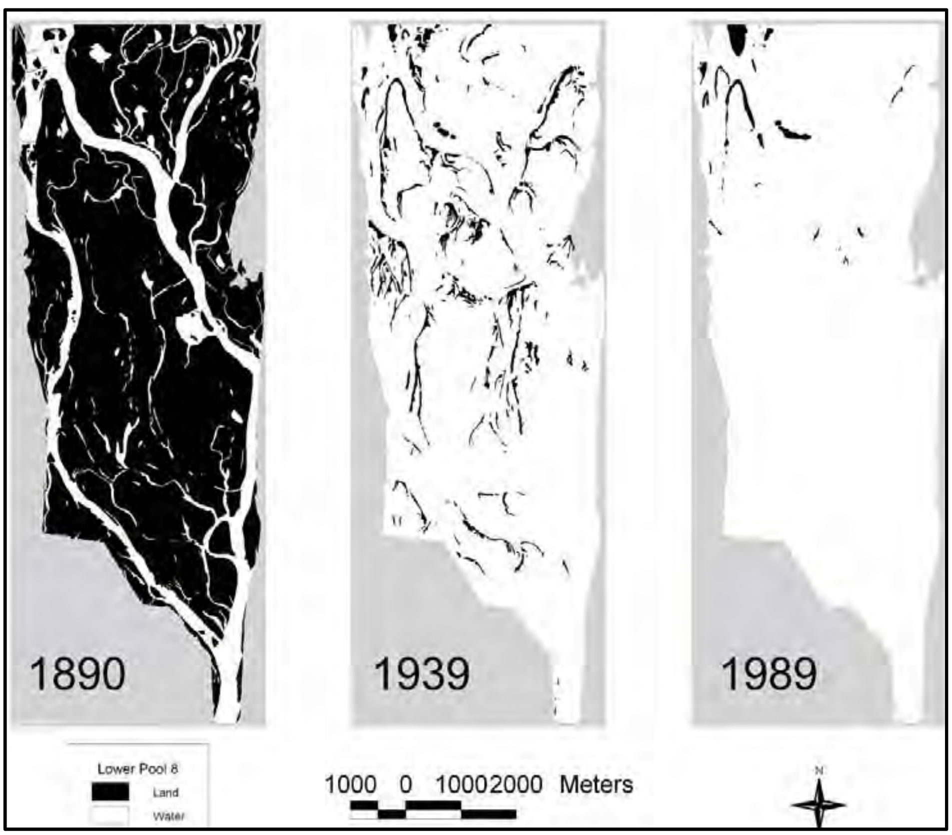


Figure 9-1. Land-Water Conditions In Lower Pool 8

The changes illustrated in figure 9-1 were typical in the navigation pools above Rock Island, Illinois and on the Illinois River. In these reaches island construction is a common management action used to reduce hydrologic connectivity (i.e. the exchange of water between channels and backwaters) and to reduce wind driven wave action. The following sections describe the conditions, problems, and opportunities in the lower and middle reaches of these navigation pools.

1. Pre-Inundation Conditions. Early surveys of the UMRS indicate a river consisting of a main channel, secondary channels, isolated lakes and ponds, and extensive floodplain areas. Connected backwaters like those that exist today were largely absent since natural levees separated the channels from the floodplain. The resulting river valley pattern has been described as classic island-braided channel morphology (USACE 2000b). This type of river planform, also known as anastomosing, is very stable due to the well-developed riparian vegetation that stabilizes river shorelines (Church 1985, Rosgen 1996, and Chen and Simons 1979), though evidence past secondary and tributary channel migration occurs in many reaches.

The majority of sediment was transported in channels, with limited sediment movement into the floodplain, even during large floods. This was due to the decrease in water velocity in the floodplain and the extensive riparian vegetation that caused sediment deposition and natural levee formation along the edges of the river channels during flood events. These natural levees were the highest features in the floodplain and after inundation became the islands that initially provided so much diversity in the lower reaches of the navigation pools. Floods and the channel/floodplain connections that formed would normally occur for short periods each year usually in the early spring or late fall.

Early efforts to make the river navigable relied on the construction of training structures including wing dams, closing dams, and revetments to increase flow in the navigation channel and scour it deeper (photograph 9-1). The River and Harbor Act of 1878 stated that a 4.5 foot channel depth was to be achieved by the closure of chutes, revetments, and contraction of the channel with wing dams (Nanda and Baker, 1984). The River and Harbor Act of 1907 authorized a 6-foot channel, resulting in additional training structure construction. Many of the wing dam fields filled in with sediment and early dredge material disposal practices sought to increase the rate of filling by placing dredge material between the wing dams. The effects of these early navigation efforts decreased the width of the main channel due to sediment deposition in the wing dams (Collins and Knox, 2003; Chen and Simons, 1979). This increased the width of the natural levees bordering the navigation channel, and along with closing dam construction, decreased connectivity between the main channel and the floodplain.

Photograph 9-1. Wing Dams at Pine Bend by Henry Bosse
The navigation channel is to the left of the main channel
Sediment accumulation in the "field" of wing dams can be seen near the center of the photograph.

Tributaries to the Mississippi River have steeper gradients than the mainstem and deliver sediments faster than the Mississippi can remove them (Fremling and Claflin, 1984). This caused the river valley to slowly aggrade since it did not have the capacity to transport all of the sediment delivered by the tributaries. Radio Carbon dating and archaeological investigations in navigation pool 10 suggest a post-glacial aggradational Mississippi River (WEST Consultants, 2000). Conversion of the watershed to agriculture and poor logging practices in the late 1800s and early 1900s resulted in a significant increase in the amount of sediment that was mobilized in the tributaries. This may have increased sediment fluxes to the Mississippi River; however, most of these sediments deposited on the valley sides or the tributary floodplain and never reached the stream network (Trimble, 1983). Those sediments that did reach the lower valley of channelized tributaries (i.e. the lower 5 to 10 miles) were efficiently delivered to the Mississippi River.

The cyclic connectivity of flows to the floodplain contributed to a diversity of community types that included permanent and ephemeral wetlands. The following excerpt from Galstoff (1924), describes a section of the Mississippi River in current day Pool 9:

> *"There are many of these lakes. Martin (1916) counted over 200 of them in an area of about 20 square miles in the Wisconsin section between Lynxville and De Soto, only the lakes that had no connection with the river being counted, the sloughs and bays being excluded. It seems that the number of lakes in the other parts of the river is not less than in this section."*

Many of these off-channel lakes potentially provided overwintering habitat for centrarchids (bluegills, largemouth bass, crappies, etc.). The diversity of backwater habitats prior to construction of the locks and dams contributed to a diverse fish community on the UMR with many lentic species represented (Janvrin, 2005). Surber (1929) described landform features of the floodplain and associated plant communities:

> *"The bottomlands between the foot of Lake Pepin and the Wisconsin River are fairly uniform in forest cover. Where the bottomlands are relatively high, usually at the head of the bottoms, the typical flood plain trees, namely, the river maples, yellow birch, elm and ash trees, are present in dense growths all over the islands or bottomlands. They occur on the banks of the chutes and ponds and the shade afforded becomes an important ecological factor limiting the life of the sloughs by preventing the growth of algae and the larger aquatic plants which constitute the food supply of plankton organisms and the substrata of aquatic insect larvae.*
>
> *Many pockets, ponds, and lakes are to be found in low places in the bottomlands or islands, more often than not in the path of some chute or slough that has been partly filled in and has ceased to function as a water course.*
>
> *The up-river ends of the bottoms are usually characterized by high banks and high land in general. Few ponds occur. Running water chutes are characteristic. They have abrupt, often undercut banks which are lined with silver maple, yellow birch, white elm, and green ash trees. Even oak trees occasionally occur on the highest land. The lower ends of the bottoms, on the other hand, are generally low and all stages in the succession of vegetational growth to the mature flood plain forest occur. Sand bars upon which only willow trees grow are found at the outer borders of the bottoms. Cottonwoods occur infrequently along the banks of sloughs wherever they do not enter into competition with the more densely foliaged trees as the maples, elms, and ash."*

While habitat and species composition within a reach is similar, additional factors (elevation, sediment type, temporal connectivity, hydrology, watershed inputs, etc.) affect habitat at more localized scales. The cumulative influence of these abiotic factors on the Mississippi River floodplain provided a diversity of habitats that change longitudinally along the mainstem of the river and laterally across its floodplain. The earliest detailed description of land cover for most of the UMR can be reconstructed through the maps and records of the U.S. Government Land Office. The pre-settlement (ca. early 1800s) land cover for this period in Pool 8 of reach 3 can be described as 21 percent open water, 14.8 percent marsh, 8 percent prairie, 55.5 percent forest and 0.6 percent swamp (USACE 2000c).

2. Resource Problems

a. Post-Inundation Conditions. Lock and dam construction created navigation pools, which are the reach of river between two dams. Water levels were raised and stabilized, permanently submerging the floodplain and most of the natural levees in the lower reaches of each navigation pool with only the highest sections of natural levees left as islands figure 9-2).

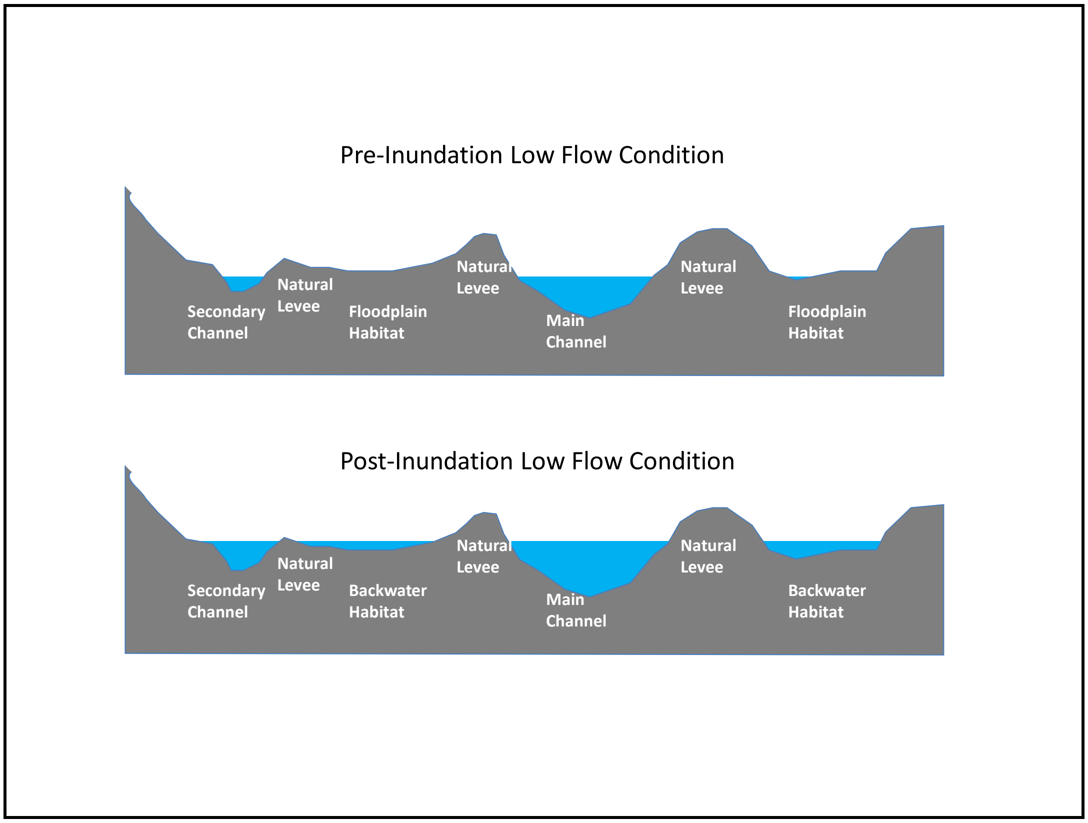


Figure 9-2. Changes Caused by Raised Water Surface Elevation in the Lower Reach of Navigation Pools

The physical changes created by lock and dam construction produced a significant change in the biological community in the lower reaches of the navigation pools. The original floodplain, which consisted of floodplain forests, shrub carrs, wetlands, and isolated lakes, was converted into a large permanently submerged aquatic system that is often categorized as impounded or backwater areas. Areas characterized as impounded are typically located three to twenty miles upstream of the dams. Backwater areas can be found throughout the navigation pool however the large backwaters where island construction is used as a management action are located in the lower half of each pool. Both the impounded areas and backwaters are characterized by large wind fetch, high hydrologic connectivity resulting in detectable water velocities throughout the area, and few to no islands.

A diverse pattern of habitat was created in the backwaters and impounded areas with a variety of aquatic vegetation types colonizing the submerged floodplain. Some of this habitat was isolated during lower flow conditions, though most of it was connected to channels. Floodplain forest persisted on islands and in areas of the navigation pools not submerged by the lock and dam backwater.

b. Existing Conditions. The conditions that existed immediately after inundation were not sustainable, and the habitat in the impounded areas and backwaters began to change. Submergence and stabilization of water levels and subsequent island erosion increased the number and size of connections between channels and backwaters and transformed them to permanent connections, rather than seasonal ones corresponding to flood events. Hydraulic connectivity between the backwaters and channels increased to high levels even during low flow conditions. Since the water levels were strictly controlled, drying out, which is essential to maintaining healthy marsh habitats, never rejuvenated the backwaters created by the 9-Foot Channel Project (Fremling, 2005). Wind driven wave action became a much more significant factor in the lower and middle reaches of each navigation pool and along with river currents resulted in erosion of many of the islands that existed after inundation (figure 9-1). The seasonal timing of sediment movement and the patterns of erosion and deposition throughout the river were altered. Sediment filled in some deepwater habitat, and sediment inputs from tributaries or resuspension by wind increased turbidity.

Aquatic vegetation generally declined from post-lock conditions, though a diverse assemblage of aquatic plants is still present, with the distribution of plant species being a function of water depth, current velocity, and water quality. The biological productivity of the nine-foot channel impoundments probably peaked out in the early 1960s (Fremling, 2005). Waterfowl exploited this artificial environment after submergence however their use evolved with time. In 1956, the peak count of Mallards reached 190,000 birds while Canvasbacks reached only 10,000. By 1978, those numbers were almost reversed, with 195,000 Canvasbacks counted on Pool 7 and 8 only and 12,000 Mallards counted, Refuge-wide (figure 8, pg 236, *Upper Mississippi River National Wildlife and Fish Refuge Environmental Impact Statement and Comprehensive Conservation Plan*, 2006).

The distribution of waterfowl habitat is a concern today with a significant amount of waterfowl using relatively short reaches of the River for resting and feeding. The US Fish and Wildlife Service (USFWS) Comprehensive Conservation Plan, 2006 describes the use of backwater and impounded habitat by migrating waterfowl as follows:

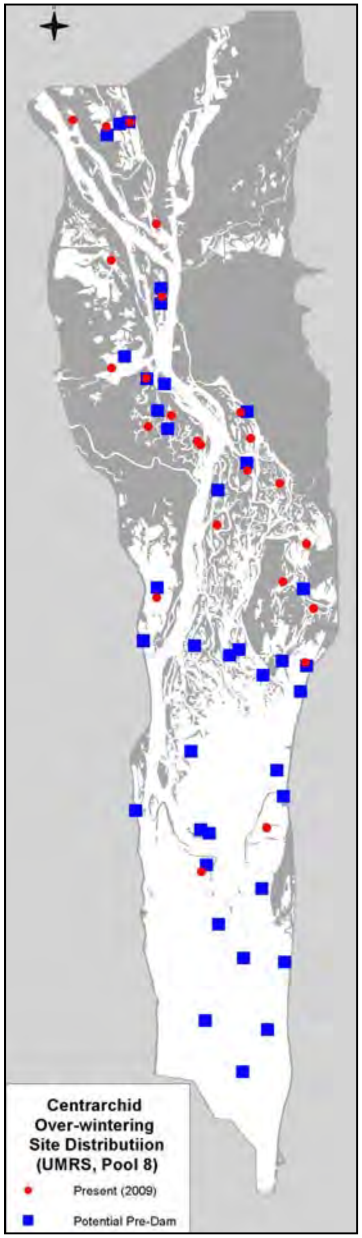
> *The UMRS refuge generally supports 60 to 75 percent (82 percent in 2005) of the Canvasbacks counted in the eastern U.S. during annual Coordinated Canvasback surveys (figure 9, pg 238, UMRS Refuge CCP, 2006). Current observations and survey data clearly show that ducks, swans and geese are not evenly distributed on the Refuge during fall migration (figures 11, 12, 13, pgs 239, 240 UMRS Refuge CCP, 2006). A key factor influencing waterfowl distribution and use of closed areas is carrying capacity, or the amount of available food for waterfowl, such as plant seeds and tubers or fingernail clams and mayflies. This carrying capacity component "is probably the most important variable for evaluating criteria for managing waterfowl closed areas" (Kenow, et al. 2003). Optimal bird distribution is achieved by providing adequate food resources (carrying capacity) where birds will not be disturbed, generally in closed areas of the refuge.*

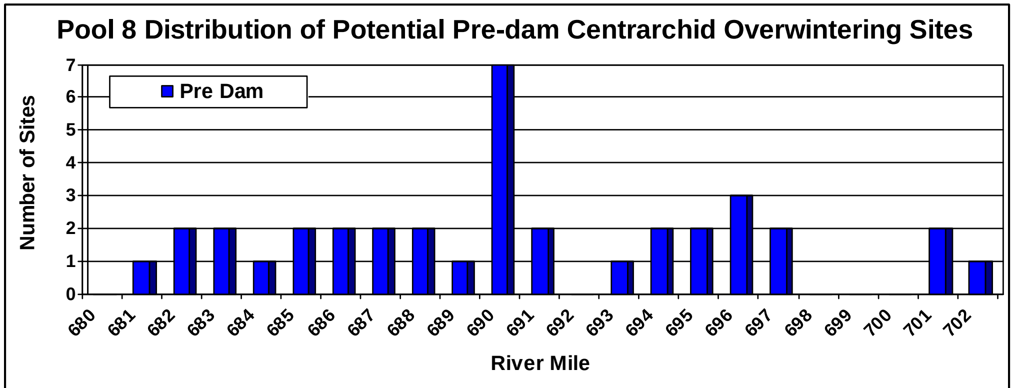
The fish community in the upper pools exhibited a similar composition to pre-impoundment, but with a possible decrease in species that utilized isolated and semi-isolated aquatic areas (Janvrin 2005). Since impounded areas and backwaters became more connected because of island erosion and shallower because of sediment deposition, the continued loss of overwintering areas utilized by Centrarchids became a major concern. The health and abundance of backwater dependent species may be affected by the quality of overwintering habitat that affects survival and body condition during the winter (Bartell, 2006). Figure 9-3 was developed by the Wisconsin Department of Natural Resources and shows the probable change in Centrarchid overwintering habitat in lower Pool 8 from pre-lock conditions to 2011 conditions. This indicates there may have been a significant loss of this habitat.

3. Resource Opportunities. The effects of inundation from the locks and dams decreased sediment transport and annual water level variation in the lower reaches of navigation pools. This greatly diminished the ability of the river to build islands through natural geomorphic processes. Island construction is an opportunity to rebuild natural levees which have eroded and to alter hydraulic connectivity and wind fetch so that they are at more desirable levels. Topographic and habitat diversity is also increased by the islands themselves.

Because of the physical changes caused by the locks and dams, the lower and middle reaches of navigation pools like lower Pool 8 were usually targeted for restoration by the interagency teams that selected project areas. The observed changes suggested a condition that would not improve during a reasonable planning horizon. Additional factors favoring these reaches include the fact that they are 100 percent federally owned which eliminated the need for a local cost-share partner; they are large areas with benefits extending over hundreds and even thousands of acres; and migratory waterfowl, a primary focus of the USFWS, who is responsible for the project after construction, use these reaches extensively during migration.

The primary physical parameters affected by lock and dam construction and that are reversed by islands are listed in table 9-1. There are other secondary parameters that are important for achieving objectives; however, they are usually linked in some way to the primary parameters. Photograph 9-2 illustrates how constructing an island reduces connectivity and sediment transport to a backwater area. Photograph 9-3 illustrates how wave action is reduced downwind of a created island.





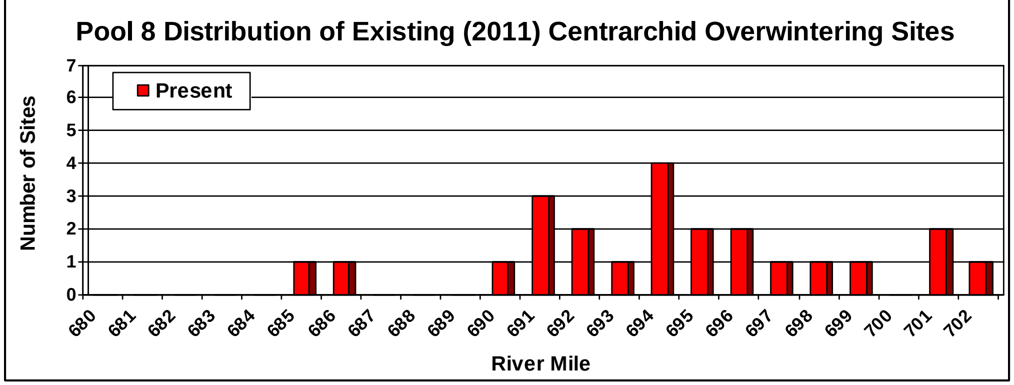
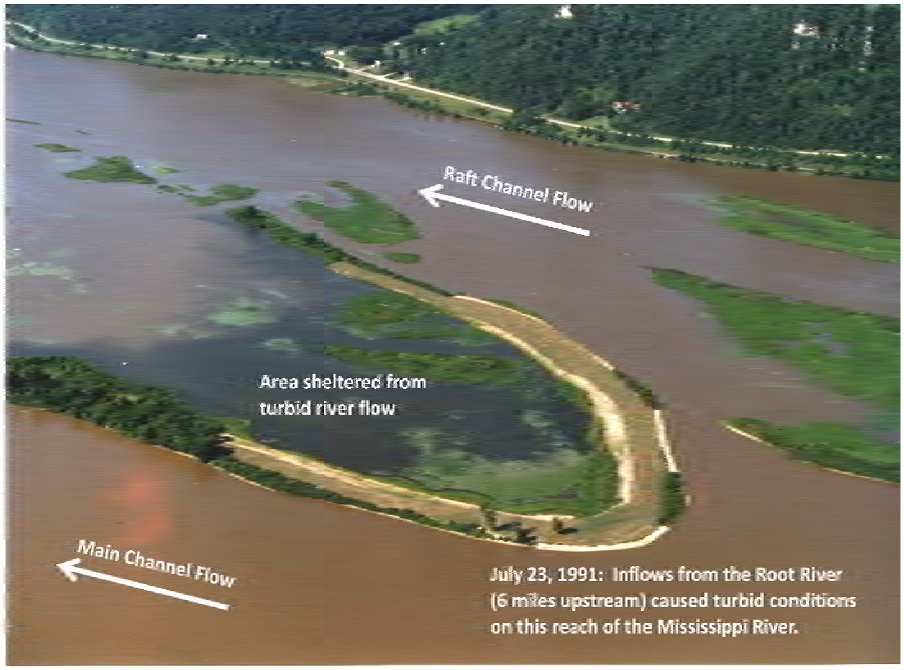


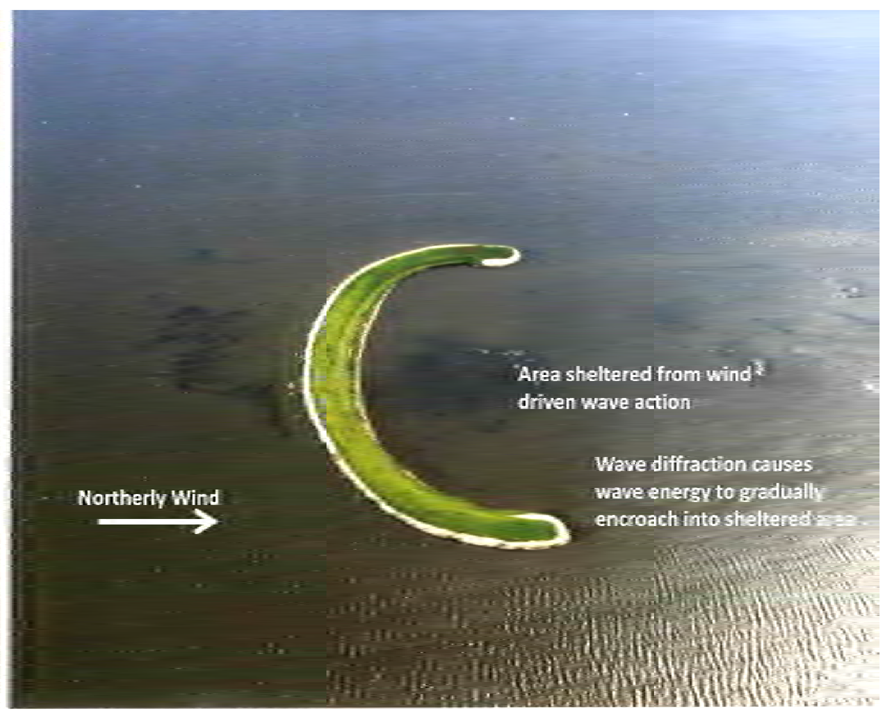
Figure 9-3. Potential Pre-Dam Distribution of Centrarchid Overwintering Habitat and 2011 Distribution of Centrarchid Overwintering Sites In Upper Mississippi River, Pool 8 (Janvrin, Wisconsin DNR, unpublished)

Table 9-1. Primary Physical Parameters in the Lower and Middle Reaches of Navigation Pools on the UMR That Were Altered by Locks and Dams and Are Partially Restored by Island Construction

Primary Parameter and Definition	**Hydrologic Connectivity:** Hydrologic connectivity can be thought of as the exchange of water from one water body to another (channels to backwaters in the case of the navigation pools). Parameters that can be used to describe hydrologic connectivity include its magnitude, duration, frequency, seasonal timing, inter-annual variability, and flow sequencing.	**Wind Driven Wave Action:** Wave height depends on wind speed and duration and wind fetch. If wave action is too severe, two problems can occur: 1) sediment resuspension, which can reduce light penetration, and 2) shoreline or island erosion, which has greatly reduced the number of islands in the impounded and backwater areas.	**Sediment Transport**: Rivers naturally transport sediment, however if the magnitude and timing of sediment transport is altered, two problems can occur. These problems include increased turbidity and reduced light penetration, which could reduce the growth of aquatic vegetation, and sediment deposition or erosion.
Pre-Inundation Condition	Although the historic values of connectivity are not known, a review of historic maps suggests a river geomorphic condition that limited flows to the main or secondary channels for "below bankfull conditions" with floodplain connectivity increasing only during flood conditions. Sediment and nutrient transport to the floodplain increased and decreased in sync with the hydrologic connectivity. A diverse array of biota and habitats existed because of these seasonal variations.	Pre-inundation wind fetch values and wind driven wave action were relatively low, probably reaching a maximum during flood events. Even during these flood events however, the existing floodplain vegetation reduced wave action and subsequent resuspension of sediments.	Since pre-inundation hydrologic connectivity was much less in the river reaches that would later become the lower and middle reaches of navigation pools, the amount of sediment transported in off-channel areas was much less. In addition, sediment that was transported out of the channels during flood events quickly settled out in the vegetated floodplain that existed adjacent to the channels. This process formed the natural levees that would later become the islands being restored through the EMP.
Existing Condition Affected by Lock and Dam but prior to Island Construction	Submergence and stabilization of water levels and subsequent island erosion increased the number and size of connections between channels and backwaters and transformed them to permanent connections, rather than seasonal ones corresponding to flood events. Today, a large amount of water is conveyed through impounded areas and backwaters in the middle and lower reaches of navigation pools. This has increased flow velocity and the flux of sediment and nutrients in these backwaters, and changes other physical and chemical parameters so that habitat conditions are degraded.	Because of the raised water surface elevation, the open water area over which waves could act (wind fetch) increased significantly. Because of this, wind driven wave action became a much more significant. This caused island erosion which further increased wind fetch and hydrologic connectivity. Resuspension of bottom sediments now occurs in response to daily wind events rather than just seasonal flood events.	Lock and dam construction altered the seasonal timing of sediment movement and the patterns of erosion and deposition throughout the river. With increased hydrologic connectivity in the middle and lower reaches of the navigation pools the continual flow of sediment into backwaters occurred. resulting in deposition. In the lower reaches of the navigation pools, the large wind fetches result in sediment resuspension and reduced light penetration on windy days.
Island Effects	Islands partially restore hydrologic connectivity to more natural levels, reducing the amount of flow entering backwaters and creating sheltered overwintering fish habitat and improved conditions for aquatic vegetation growth	Islands reduce wind fetch which reduces sediment resuspension, improves light penetration, and improves aquatic vegetation growth.	Islands reduce the amount of sediment that enters backwaters since hydrologic connectivity is reduced. Sediment resuspension is also reduced since wind fetch and wind-driven wave action are reduced.



Photograph 9-2. Example of Reduced Connectivity and Sediment Transport



Photograph 9-3. Example of Reduced Wave Action and Sediment Resuspension

4. HREP Objectives. Islands are designed and constructed to achieve a set of project specific objectives and performance criteria that are developed by the interagency teams based on the habitat needs of biota. Objectives are statements of the desired condition of an ecosystem. They describe hydraulics and hydrology, biogeochemistry, geomorphology, habitat, and biota. Performance criteria are measurable attributes of ecosystem objectives e.g. acceptable range, thresholds, or limits; based on scientific understanding of target future ecological conditions (adapted from Harwell et al. 1999). Performance criteria associated with each objective can be developed to make the objective more specific and quantitative (e.g., secchi depth should exceed 60 cm in backwaters). Together these objectives and performance criteria become the desired future condition, or a virtual reference condition for a specific project area. The project specific objectives are derived from the much more general objectives that are set at the larger reach or system scales. Project objectives usually involve physical/chemical objectives such as reducing inflows (i.e. hydraulic connectivity) or increasing light penetration; and habitat/biota objectives such as increased submerged aquatic vegetation, or improved waterfowl habitat. These objectives are usually stated separately however they are usually directly related to each other.

Figure 9-4 is a conceptual model illustrating the relationship among project scale habitat objectives, performance criteria, and management actions. In this figure, the project scale habitat objective, diving duck migratory habitat, can only be achieved if certain physical, chemical, and biological objectives and criteria are met. These objectives and criteria are organized by the essential ecosystem characteristics of geomorphology, hydraulics and hydrology, biogeochemistry, and biota. Management actions that might be taken to meet the criteria and achieve the habitat objective are shown in the boxes on the right side of the diagram. Essentially the management actions alter the geomorphic (connectivity and wind fetch) or hydraulics and hydrology (water level variation) characteristics of the project area, to improve biogeochemistry (water clarity) so that that aquatic vegetation will be at optimal levels and provide the needed food requirements for diving ducks during migration. The PDT working on a project can develop information such as the number of acres of habitat to restore, or the required reduction of inflows or wind fetch. In this conceptual model, island construction could be used to meet several of the geomorphic and hydraulic criteria.

A new island essentially becomes the new natural levee, separating channels from backwaters, reducing hydrologic connectivity, and increasing channel flow. Wind fetch and wave action are reduced in the vicinity of islands, reducing the resuspension of bottom sediments and shoreline erosion. Islands change the temporal patterns of sediment and nutrient transport to backwaters so that it occurs with seasonal high flow events which overtop the islands. Islands do not stop sediment deposition from occurring, but they do reduce the rate of sediment deposition, and the patterns of scour and deposition as a means to improve habitat quality and diversity. Constructing islands is a necessary step in partially restoring the habitat value in the lower portions of these navigation pools.

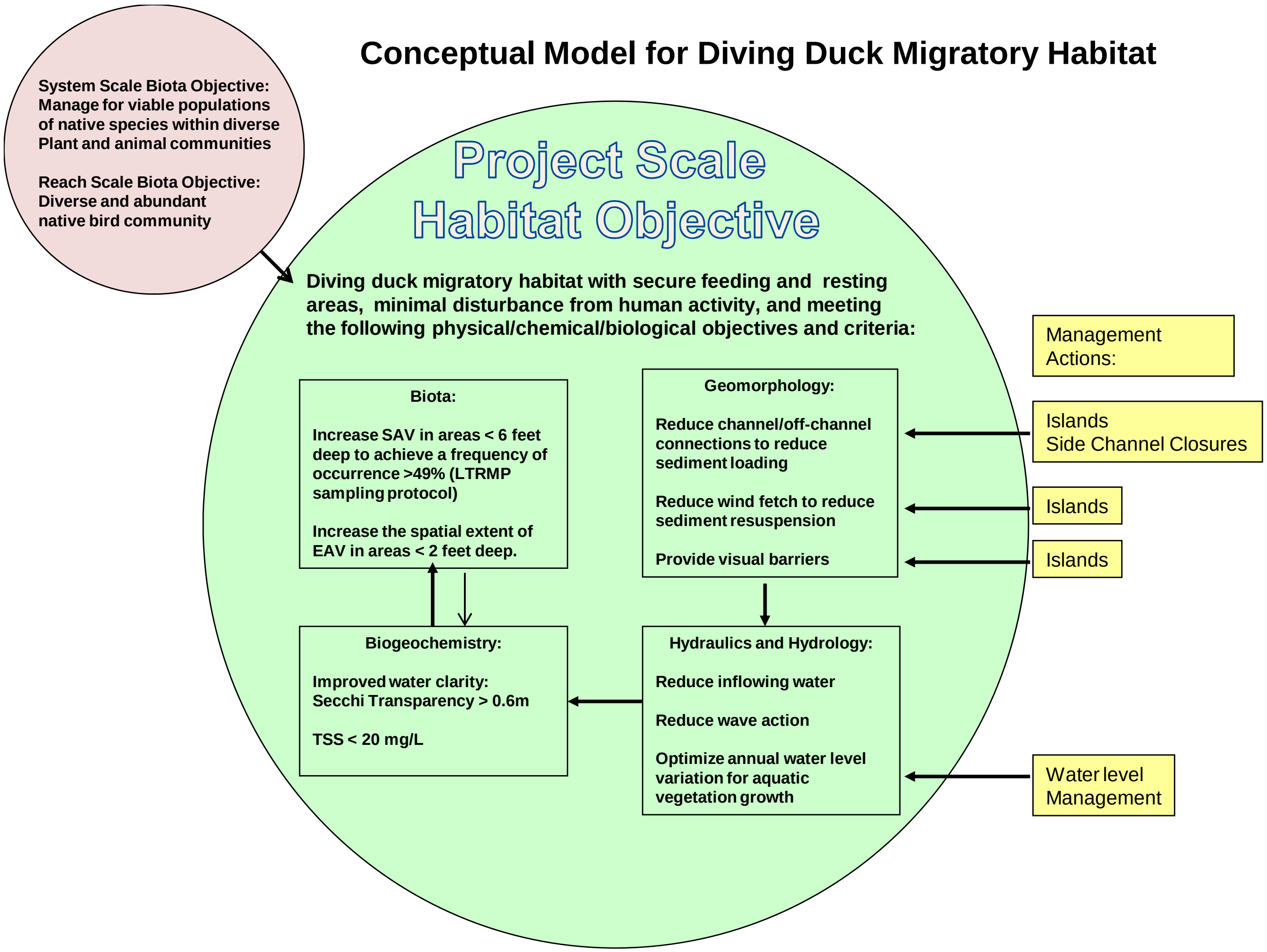


Figure 9-4. Conceptual Model for Diving Duck Migratory Habitat Illustrating the Relationship Among Objectives, Performance Criteria, and Management Actions

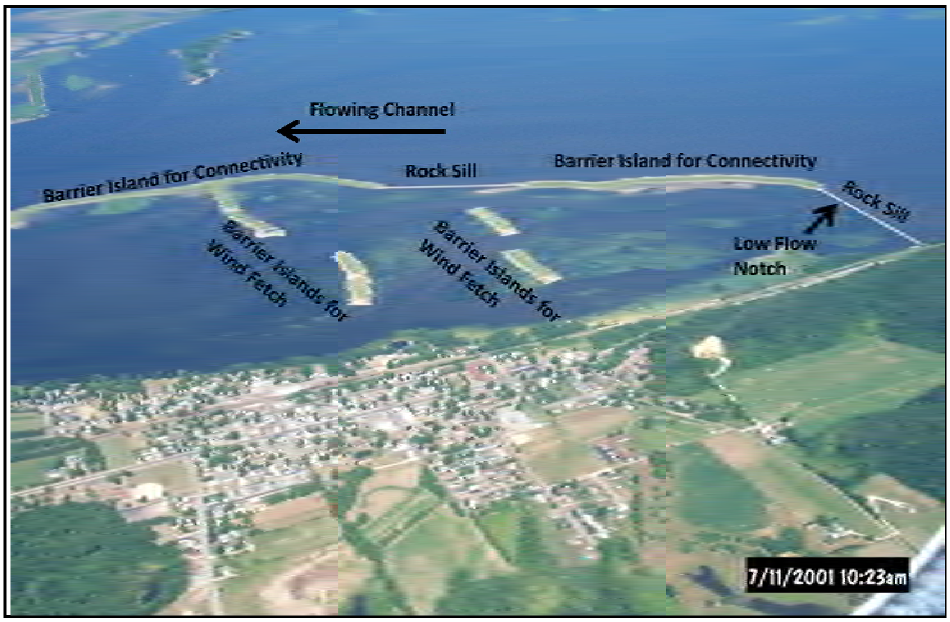
B. BARRIER ISLAND CONSTRUCTION

The tables in the following sections list design criteria that have been developed for islands. The criteria are listed in six different tables that cover six different design categories: 1. island layout; 2. elevation; 3. width; 4. side slope; 5. topsoil and vegetation; and 6. shoreline stabilization. Each of the tables is subdivided into 4 design disciplines: geomorphology, engineering, constructability, and habitat. References linking the design criteria to the Physical River Attributes (Appendix 9-A), Habitat Parameter (Appendix 9-B), Engineering Consideration (Appendix 9-C), or Lesson Learned (tables 9-11 to 9-17) that the criteria is based on is provided. These design criteria are based on lessons learned from nearly 20 island projects that have been constructed in the last 25 years through the UMRR-EMP. Although the term adaptive management usually implies monitoring, learning, and adjusting to improve ecosystem response, the same process has been used to improve island planning, design, and construction. These design criteria should be used as a guide for designing island projects however each project has its own unique characteristics that will require adjustments. In some cases, the design criteria conflict with each other, and the interagency project design team will have to make decisions to resolve these conflicts based on project specific conditions. The creative talents of design teams will continue to produce new innovations and new lessons learned.

1. Biota or Habitat Considerations. In almost all cases, the teams working on island projects designed islands that reduced inflows to project areas or reduced wind-driven wave action within the project areas. Fisheries managers knew that over-wintering habitat for many species of fish required low current velocities, adequate dissolved oxygen, and warmer winter water temperatures. Waterfowl managers understood the importance of submerged aquatic vegetation, which grew best in lower flow environments with reduced wave action, and the need to minimize disturbance to waterfowl by people. The public had observed the loss of islands and experienced the effects of sediment deposition since the locks and dams had been constructed. All of this information and knowledge pointed towards the need to restore the islands that had existed and to reduce the amount of backwater flow (hydrologic connectivity) or wind fetch in project areas. Islands were the logical choice to do this. The islands would result in the partial restoration of natural levee function and in a hydrologic regime that reflected more natural seasonal variation in flow rates. During summer and winter low flow conditions, backwater flow would be reduced enough so that water velocity, temperature, and dissolved oxygen concentration were at more desirable levels. Some sections of the islands were constructed at low elevations so that during high flow conditions that typically occurred in the spring, flow conveyance was maintained. Movement of aquatic organisms into the areas sheltered by the islands was maintained by leaving openings in the islands (usually near their downstream end).
The majority of islands designed and constructed to date were based on goals and objectives for aquatic habitats. However, terrestrial habitat is created by the islands themselves, and island elevation (and in some cases topsoil depth) is varied to produce more diverse terrestrial habitat. A variety of tree species are planted on the islands to diversify the terrestrial habitat that results.

2. Design Considerations – Layout. Islands are usually positioned over historic islands or natural levees that were submerged or eroded once the water was raised in the navigation pools. This partially restores natural levee function and the seasonal variation in hydrologic connectivity since the new island creates a barrier separating flowing channels and backwaters. The only time water exchange occurs is during flood events when the islands are overtopped. Essentially, the historic position of the natural levees became the reference condition for the project. An exception to this is islands that are positioned to reduce wind fetch and wind driven wave action. This results in islands not necessarily positioned on the natural levees, but positioned to have the greatest effect on wind fetch and wave action. Photograph 9-4 shows the constructed islands for the Pool 8, Phase II project (1998) with various project features labeled. The barrier islands were constructed to reduce hydrologic connectivity and wind fetch. The design included rock sills that are overtopped during floods to provide floodplain flow and a low flow notch to provide small amounts of flow to the area at all times.

Other reasons to position the islands over the historic natural levees include reduced quantities and costs since these are often the shallowest areas, better geotechnical stability since these natural levees were preloaded by the island that once existed there, and better shoreline stability since wave action and river currents are lower in shallower areas. Table 9-2 summarizes design considerations for island layout.



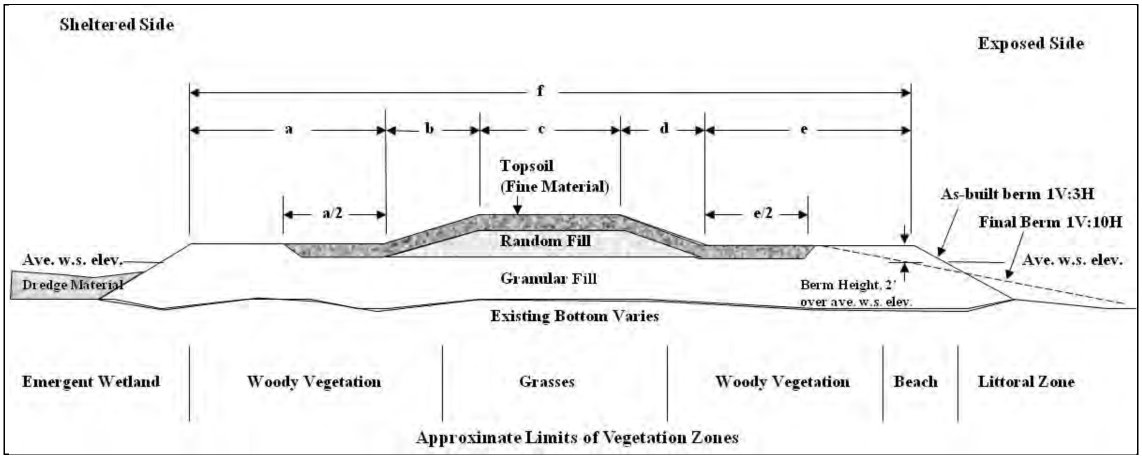
Photograph 9-4. Island Layout for Pool 8, Phase II (Stoddard Bay, Wisconsin)

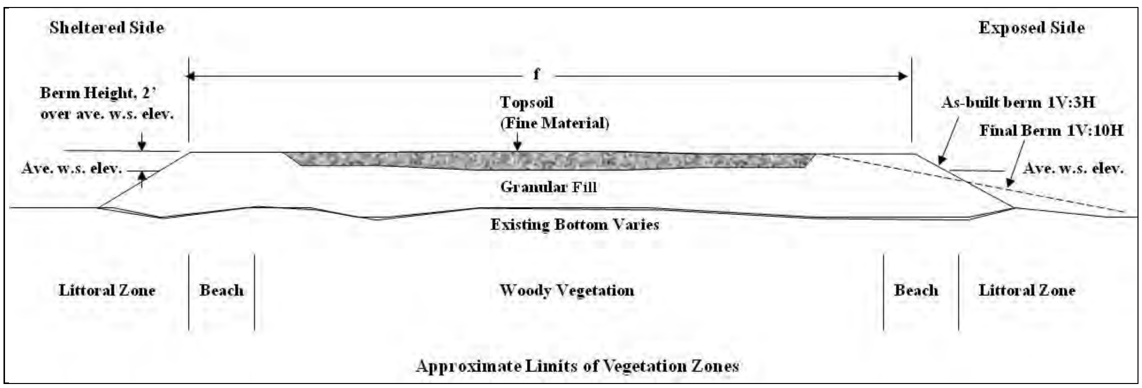
Table 9-2. Design Criteria for Island Layout

Design Discipline	Design Criteria
Geomorphology	1.a Restore a riverine flow regime by rebuilding eroded natural levees along the main and secondary channels. For below bankfull flow conditions, the majority of the flow conveyance should be in channels. *Physical River Attributes 1 – 5, 7; Engineering Consideration 4 (App. 9-C)* 1.b Spacing between islands and the resulting wind fetch should account for the water depth of the area that is sheltered by the island during the growing season. Wind fetch should be reduced enough so that sediment resuspension for the design wind is prevented. The following table provides guidance based on calculated shear stress generated by wave action for a 20 mph wind. Water depth (feet) 2 3 4 Fetch (feet) 3500 6000 9000 *Lessons Learned 1.H.3 Engineering Consideration 4 (App. 9-C)*
Engineering	1.c Locate islands in shallow water to reduce costs and erosion potential. A 50' buffer of shallow water should be left between the island shoreline and the adjacent channel or access channels. *Lessons Learned 1.A.2, 1.B.6, 1.C.1, 1.D.2, 1.K.1, 1.P.2, 1.Q.2* 1.d. Position islands over pre-loaded historic island locations to minimize displacement of existing substrate (i.e. mud-wave formation) and long-term settling. *Lessons Learned 1.P.2, 1.Q.2* 1.e Incorporate existing island remnants into or adjacent to new island to reduce material quantities, shoreline erosion, and substrate displacement, and for aesthetics. *Lessons Learned 1.D.1, 1.H.1* 1.f Position islands perpendicular to flow and dominant wind fetch to have the greatest physical effect unless other factors listed in this table influence the layout. *Lessons Learned 1.B.1, 1.B.2, 1.E.1* 1.g Two dimensional numerical hydraulic models should be used to finalize island positions. *Lessons Learned 1.H.4, 1.P.3, 1.Q.3*
Constructability	1.h Minimize access channel dredging, by positioning some reaches of islands closer to deep water while maintaining the 50' buffer described above. *Lessons Learned 1.D.3* 1.i. Use construction pads to access islands to avoid dredging access channels. In some cases the access pads can be left to provide turtle nesting habitat. *Lessons Learned 7.O.1*
Habitat	1.j Maximize habitat area sheltered by island. Islands should be positioned so that physical/chemical parameters for fish habitat (velocity, water temperature, dissolved oxygen, and depth) and aquatic vegetation (turbidity, wind fetch, velocity) are at optimal levels. The value and range of variation in these parameters should be based on input from PDT members and from the research community. The occurrence of coldwater eddies at the downstream end of islands should be taken into account, if overwintering habitat is one of the objectives. *Lessons Learned 1.A.1, 1.B.1, 1.B.2, 1.B.3, 1.B.5, 1.E.2, 1.H.2, 1.H.3; Habitat Parameters 1,2,3 (App. 9-B); Engineering Consideration 4 (App. 9-C)* 1.k Islands should be positioned so they create multiple waterfowl resting and feeding areas, visual barriers to prevent disturbance, and littoral/riparian areas that provide thermal cover and loafing structure. Thermal cover is provided by the sheltered zone immediately downwind of an island which equals 10 to 50 times the island and tree height. *Lessons Learned 1.P.1, 1.Q.1; Physical River Attribute 1 (App. 9-A); Habitat Parameters 2 & 5 (App. 9-B); Engineering Consideration 4 (App. 9-C)*

3. Design Considerations – Cross Section. Figure 9-5 shows typical island cross sections that are used on HREP projects (though many variations exist). Note that emergent wetlands can be included on the sheltered (or backwater side) on each of these cross sections, though it is only illustrated on the top cross section. Islands have a main section with berms on either side. The berms are represented by dimensions “a” and “e” in figure 9-5 and are constructed to an elevation between 1 and 2 feet above the average water surface elevation. They provide sacrificial sand for beach formation, which occurs due to wave action, and substrate for willow growth, which prevents erosion of the main section of the island during flood events. The elevation and width of the main section is a function of habitat objectives, engineering considerations such as flood conveyance needs and stability, economics, stability, and lessons learned. Early designs in the mid to late 1980s resulted in islands constructed to a 10-year flood elevation or higher. The higher islands, it was believed, would be more stable due to less frequent overtopping and provide a greater barrier to sediment laden flow from the main channel, reducing sediment deposition in backwaters. With the occurrence of several floods in the 1990s, it became apparent that islands were stable during overtopping events as long as the water surface differential from one side to the other was less than 0.5 feet and as long as there was topsoil and vegetation on the island. This led to lower design elevations, and in some cases, a flat profile resulted as shown in the second cross section in figure 9-5.

Fish and wildlife habitat goals and objectives have become more diverse over time with a focus on many different species, resulting in greater variation in island elevation, cross section, layout and vegetative plantings. The Lake Onalaska Islands constructed in 1989, consisted of a single uniform cross section throughout the project and one vegetation scheme, while the Polander Lake Island project, constructed in 2000, consisted of 6 different cross sections, 6 different tree and shrub planting schemes, and 4 different grass/forb planting schemes. Pool 8 Islands, Phase III, constructed in 2007-2011 was the largest island restoration to date, with more than 30 cross-sections. Tables 9-3. 9-4, and 9-5 summarize design considerations for island cross section including elevation, width, and side slope.





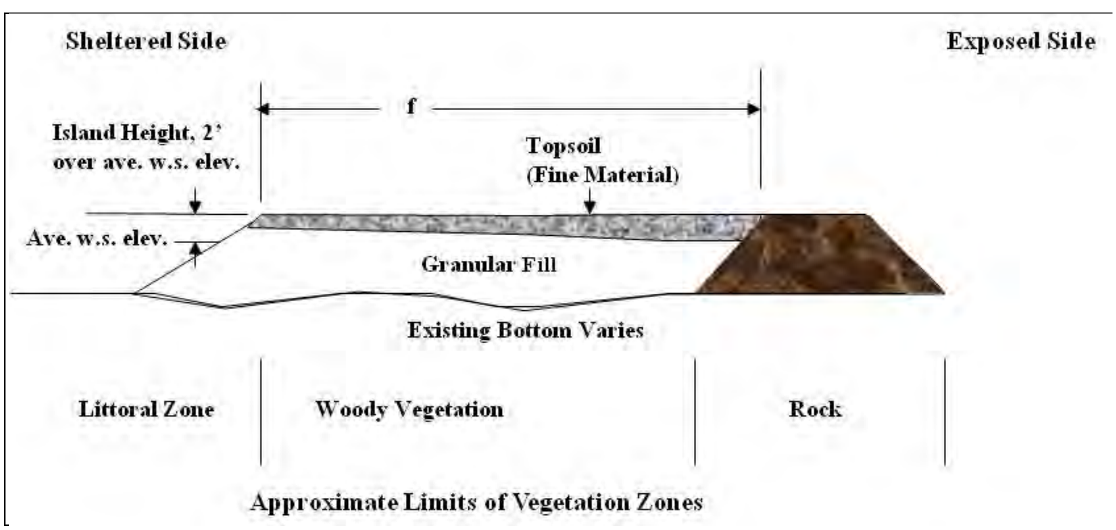


Figure 9-5. Island Cross Sections Typically Used for Island Construction

Table 9-3. Design Criteria for Island Elevation

Design Discipline	Design Criteria
Geomorphology	2.a Islands should be constructed with a top elevation near the bankfull flood elevation to create hydraulic and fluvial conditions similar to those that existed for natural conditions. The bankfull flood elevation has a recurrence interval of 1.5 to 3 yrs. A higher elevation may be used in some reaches to achieve objectives for terrestrial vegetation. *Physical River Attributes 5, 7 (App. 9-A); Engineering Consideration 3 (App. 9-C)*
Engineering	2.b Islands should be stepped down in elevation in the downstream direction so that during floods, overtopping of each island section progresses in a downstream to upstream direction reducing the head differential and erosion potential of the next upstream section. The rate at which the island is stepped down should be based on the water surface slope, to ensure this downstream to upstream progression. *Lessons Learned 2.D.4,2.H.1* 2.c Rock sills can be incorporated into islands to provide floodplain flow/conveyance for more frequent floods. They should also be considered in cases where an island would be constructed across an existing secondary channel. Rock sills should have a lower elevation than the earth islands so flow first occurs over the sills reducing hydraulic forces across the earth islands during later stages of the flood. *Physical River Attributes 5,7 (App. 9-A); Lessons Learned 2.E.1, 2.H.1; Engineering Considerations 2, 3 (App. 9-C)* 2.d The berms, constructed on either side of the island for stabilization, should be 1 to 2' above the average water surface elevation to provide optimum conditions for terrestrial vegetation growth. Usually 2' is recommended so that there is enough sand in the berm for beach building; however, a 1-ft high berm is better for Willow growth. *Lessons Learned 2.A.2, 2.B.2, 2.C.2, 2.D.4* 2.e Minimize flood impacts by choosing low elevation islands. If higher islands are included in the design, they should be aligned in an upstream/downstream orientation, so that impacts on flood elevations are minimized. If island elevations vary, the highest elevations would usually be at the upstream end of the island sloping downstream and/or away from adjacent channel to mimic natural island morphology. 2.g Sufficient soil borings should be obtained along the island alignment so that initial and long-term settlement can be estimated. Island top elevation should be adjusted to account for settlement. *Lessons Learned 2.D.4*
Constructability	2.h Construction tolerances should result in the desired final elevations and topographic variations. The term *micro-topography* is sometimes used and this simply means the variation in island elevation that occurs over relatively small spatial scales compared to the overall project scale. 2.i Provide at least a 3-ft base of sand for heavy equipment to operate on. In shallow water conditions, this might require that the island elevation be higher than is desired. If the existing substrate consists of sand, a base thickness less than 3' can be considered. *Lessons Learned 2.K.1* 2.j Excess material (i.e. if the contactor stockpiles too much material) should be incorporated in the island by increasing width or length, not elevation. *Lessons Learned 7.C.4, 2.H.4*

Table 9-3 (cont). Design Criteria for Island Elevation

Design Discipline	Design Criteria
Habitat	2.k Design elevation should provide desired terrestrial vegetation. Islands higher than 5' over the average water surface retain their grass cover for longer periods of time, while islands lower than 5' tend to convert over to herbaceous and woody vegetation. Other factors such as topsoil depth, also affect vegetation communities. *Physical River Attribute 9 (App. 9-A), Lessons Learned 2.A.1, 2.A.2, 2.B.1, 2.B.2, 2.C.1, 2.C.2, 2.D.1, 2.D.3; Habitat Parameter 4 (App. 9-B)* 2.l Vary island elevations from around a 2-yr flood elevation to a 10-yr flood elevation to provide topographic and subsequent vegetation diversity. *Physical River Attribute 9 (App. 9-A); Lessons Learned 2.A.1, 2.A.2, 2.B.1, 2.B.2, 2.C.1, 2.C.2, 2.D.1, 2.D.3; Habitat Parameter 4 (App. 9-B)* 2.m If the island function includes creating sheltered winter habitat for fish, the top elevation should result in infrequent overtopping during the winter months (December through February). *Habitat Parameter 1 (App. 9-B)* 2.n On extremely sheltered shorelines, sand flats or mudflats can be constructed. The average elevation of these features should be set 0.5' below the average water surface elevation that occurs during the fall migration. The micro-topography on these features is important and should result in alternating areas of habitat that are submerged or emerged by up to one foot. Variation in elevation can be achieved by frequently moving the dredge pipe. *Lessons Learned 2.P.1, Habitat Parameter 5 (App. 9-B)*

Table 9-4. Design Criteria for Island Width

Design Discipline	Design Criteria
Geomorphology	3.a When it is desirable to decrease floodplain discharge during floods, use the greatest feasible width. Hydraulic slope, flow velocity, and discharge decrease with increased island width during overtopping floods so wider islands can be a factor in restoring a riverine flow regime with a more desirable floodplain to channel discharge ratio during floods. *Physical River Attributes 4, 5, 7 (App. 9-A)*
Engineering	3.b Lower sections of island that are overtopped more frequently should be wider than higher sections. The hydraulic slope, flow velocity, and potential for erosion decreases with increased island width during overtopping floods. Typical widths used on previous projects (70 to 200 foot base width, 10 to 100 foot top width) have resulted in stable islands in almost all cases. Some erosion and breaches have formed on islands with top widths of 10 to 40 feet, suggesting that from a stability standpoint, island widths should be greater than 40 feet. *Lessons Learned 3.G.1, 3.I.1, 3.P.1, 3.P.2; Engineering Consideration 5 (App. 9-C)* 3.c Overall island width should be large enough so that the activities of burrowing animals will not create a continuous pathway through the island. *Lessons Learned 3.H.3* 3.d Berm width should be wide enough to provide adequate material for beach formation (the process where sand in the berm is reshaped by wave action into a gradually sloping beach) and still allow a stable 20-foot wide above-water strip for terrestrial vegetation growth. The standard berm width used on the latest projects is 40 feet, however widths have varied from 20 to 60 feet. A wider vegetated berm provides better stability during floods because there is more vegetation to dissipate wave energy. It also provides a larger buffer, in case shoreline erosion is greater than expected. *Lessons Learned 3.B.1, 3.D.1, 3.D.2, 3.H.1: Engineering Consideration 6 (App. 9-C)*
Constructability	3.e Use a minimum of a 100-foot base width when 16-inch to 24-inch hydraulic dredges are used for construction. Narrower widths will require excessive berming to contain the dredge plume. Mechanical placement of dredge material should be considered if a narrower width is desired. *Lessons Learned 3.C.1, 3.K.1* 3.f Rock sill widths are usually set at 10', however if the rock sill will be used for equipment access, widths as large as 25' have been used. *Reference Lesson Learned 3.S.2* 3.g The minimum working width on earth islands for efficient equipment operation is 40 feet, though there may continue to be reasons to use a lesser width such as reducing the impact to existing habitat. *Lessons Learned 3.K.1, 3.S.1* 3.h. Hydraulic placement of fine material will require a wide island cross-section so that a containment cell can be constructed to allow for adequate settling of sediment in the dredge slurry. Mudflats can be added as a feature to provide a containment cell to meet water quality limits. *Lessons Learned 3.A.1, 5.H.2*
Habitat	3.i Wider islands create better visual barriers preventing disturbance of waterfowl by commercial and recreational vessels during migration.

Table 9-5. Design Criteria for Island Side Slope

Design Discipline	Design Criteria
Geomorphology	4.a Wave action on shorelines with sand substrate results in erosion and subsequent formation of a beach with a slope of 1V:8H or flatter. *Lessons Learned 4.A.2, 4.D.2*
Engineering	4.b Use side slopes of 1V:5H or flatter to reduce rill erosion due to rainfall runoff from the top of the island. *Lessons Learned 4.A.1, 4.B.1* 4.c Where riprap is being used, side slopes should be 1V:3H or steeper to reduce rock quantities. 4.d If ice forces are a problem, riprap side slopes should be 1V:4H or flatter. *Lessons Learned 4.B.2*
Constructability	4.e An underwater side slope of 1V:3H is usually specified so that material quantities can be determined. However, attempting to construct the underwater portion of the island is difficult to do and inspect. The bottom line is to provide enough material in the island berm so that erosive forces (wave action, river currents, ice) can form the underwater portion of the island (i.e. the beach). *Lessons Learned 4.D.2* 4.f A flatter side slope improves the constructability of islands that are constructed using fine sediments. *Lessons Learned 4.J.1*
Habitat	4.g Flatter slopes provide better habitat for shore birds, wading birds, nesting turtles, and a variety of other species. However, a flat slope near the average annual water level will be quickly colonized with woody vegetation, which may eliminate shorebird habitat and create a barrier to nesting turtles. Side slopes are usually not based on habitat. *Lessons Learned 2.A.2, 2.C.2, 2.D.3, 4.D.1; Habitat Parameters 4, 5, 6 (App. 9-B)*

4. Design Considerations – Earth Material Types and Vegetation

a. Earth Materials. Table 9-7 lists design criteria for earth material types used to construct islands. The earth material types used in island cross sections varies depending on local conditions, and has evolved over time. Islands constructed prior to 1990 consisted of a sand (or granular fill) core with a 6 to 12 inch layer of topsoil spread over the sand. Fine sediments are defined as silts and clay size material passing the no. 200 sieve or the .075 mm sieve. With Boomerang Island, constructed in 1992, a sand base that was one to two feet above the average water surface was constructed first. Then the island was completed by placing up to a 4-foot layer of sediment on top of the sand (photograph 9-5).

Photograph 9-5. Pool 8, Phase I, Stage II, Boomerang Island

Because of concerns over the amount of access dredging required for island projects, and the unknown types of material that came out of access channels, island designs beginning with the Pool 8, Phase II Islands (1999) included random fill in the cross section. The resulting composite cross section consisting of a sand base, random fill, and topsoil (figure 9-5) continues to be used on many island projects, including Spring Lake in Pool 5, Polander Lake in Pool 5A, the Pool 8 Islands, and Capoli Slough in Pool 9. Table 9-6, which provides information on the quantities of sand and fines that were used on three recent island projects, indicates that the majority of the earth material used is sand.

Table 9-6. Sand and Fines Quantities on Island Projects

	Polander Lake	**Pool 8, Phase III, Stage 3A**	**Pool 8, Phase III, Stage 3B**
Island Length (feet)	9,200	11,300	7,160
Granular Fill (cubic yards)	176,000	340,000	165,000
Random Fill (cubic yards)	33,000		
Fine Material (cubic yards)	30,000	37,000	16,000
Total Fill (cubic yards)	239,000	377,000	181,000
Percent Sand	74	90	91
Total fill/foot of length (cubic yards)	26.0	33.4	25.3

Several island projects included an outside containment berm usually made of granular fill with in-situ sediment dredged from the adjacent backwater placed in the area contained by the berm. Examples of this type of construction include islands constructed at Bertom McCartney and Sunfish Lake in Pool 11. This type of construction technique results in very thick layers of random fill. A few island projects have been constructed by side casting dredge material from adjacent backwater dredging. Side cast islands include those at Swan Lake (1996) and Peoria Lake (1997) on the Illinois River, Mud Lake in Pool 11 and Tilmont Lake Peninsula (2002). The Peoria Lake Island on the Illinois River, which will be completed by 2013, consists of geotextile containers filled with sediment. Another construction technique includes constructing a narrow island with rock fill. This was used for the Pool 9 Island project (1994).

The top soil thickness varies from 6 to 12 inches with 6 to 9 inches usually called out on lower elevation islands and 12 inches on higher islands. There remains some debate as to the thickness of topsoil that is needed and with topsoil accounting for as much as 25 percent of project costs, reducing thicknesses even by a few inches can reduce costs significantly. However, there is a desire to maximize the use of fines dredged from backwaters since this dredging increases backwater depth, creating fish habitat. In addition, if island stability or the establishment of woody vegetation is the primary criteria, experience suggests that a thicker layer of topsoil is desirable.

The fine sediments placed on islands have cohesive properties, which resist erosion. In 1993 and 2001 recently constructed islands were overtopped by floods before significant vegetation could be established on them. In cases where a layer of topsoil had been placed on the island, erosion was usually minimal. When topsoil had not been placed and sand was exposed to wave action and/or river currents during the flood, significant erosion usually occurred (photograph 9-6). This photograph shows one of several sections of island that were intended to provide sandy substrate for turtle nesting. Several of these sections were severely eroded when they were overtopped by 1 to 2 feet of water during the 2001 flood. The adjacent island sections were stable because of the topsoil and grass growing on them. The fix that was implemented here was simply to line the existing cut with rock or cobbles so that it would not get any larger.

Photograph 9-6. Pool 8, Phase II, Slingshot Island

Anfang and Wege (2000) measured the percent fine sediments in the topsoil of various islands and found: 27 and 32 percent on Swan and Mallard Island in Pool 5, 37, 38, and 51 percent on Broken Gun, Cormorant, and Arrowhead Islands in Pool 7, and 42 and 36 percent on Horseshoe and Boomerang Islands in Pool 8. USACE surveys indicate a clay, silt, sand fraction that averaged 61, 27, and 12 percent for surface substrate on Boomerang Island based on 5 samples. The reason for the discrepancy with Anfang and Wege is not known, but may be related to differences in the sampling technique (i.e. a surface grab sample will tend to have fewer fines than a deeper core). Anfang and Wege (2000) concluded that there should be an upper limit to the percent fines contained in the topsoil, because material with too many fines tends to harden and become impermeable to rain infiltration. The specification of 40 to 70 percent fines has become the standard as of this date. Random fill does not have a specified gradation other than it must be suitable material for construction.

b. Vegetation. Table 9-7 also lists design criteria for vegetation on islands. Vegetation reduces erosive forces before they cause erosion on the islands and provides habitat. The four vegetation zones that can occur on islands include grasses (and sometimes woody vegetation) on the higher main section of the island, woody vegetation on the low elevation berms, a beach zone which might form along the land-water interface, and an off-shore littoral zone along the shoreline. Depending on a variety of factors including the planting plan, island elevation, soil compaction, and topsoil thickness, and the amount of wave action, one or more of these zones may be absent. Some examples of the variability in vegetation include: 1)low elevation islands tend to be colonized with woody vegetation across the entire island, eliminating the grasses 2) greater topsoil thicknesses tend to favor tree establishment, 3) shorelines in sheltered areas may have woody vegetation right to the water's edge, eliminating the beach zone. At the Swan Lake project on the Illinois River, vegetation that was planted on the islands was quickly grazed by waterfowl leaving these islands relatively bare during the first few years after construction. Protecting the island vegetation with bird netting or other techniques until the vegetation has matured adequately would have improved conditions on the island.

The choice of grasses or legumes planted on islands is based on habitat management objectives, not on erosion resistance. Obviously the establishment of vegetation increases stability, however, if adequate topsoil has been placed, island erosion during overtopping has been minimal, and the specific type of vegetation doesn't seem to be a significant factor. Most of these islands have been planted with various mixtures of native prairie grasses and legumes (photographs 9-7 and 9-8). As shown in photograph 9-7, a variety of conditions existed on the Polander Lake Islands 4 years after they were constructed and 3 years after planting. Fairly dense cover with good species diversity can be seen in the foreground. Areas of bare soil can also be seen. Photograph 9-8 shows the conditions that existed on the Spring Lake Islands just a couple years after construction. The aquatic area to the right of the main part of the island in this photo is a mudflat that was created as part of this project.

Photograph 9-7. Pool 5, Spring Lake Islands

Photograph 9-8. Polander Lake Islands

Anfang and Wege (2000) conducted extensive surveys of the vegetation communities on island projects and dredge material sites. They developed recommendations for site management based on their observations that can be used as a guide in choosing vegetation types for islands. Given that all sites tend to be colonized by woody vegetation eventually, they suggest that design factors such as the thickness of fine material, percent fines in topsoil, species selection, and island elevation be more rigorously tested to determine how to maintain grassland cover over time. Management activities such as controlled burning, fertilization, mowing, or second seedings were suggested to maintain grasses. Nissen (pers. comm.) has observed that overtopping of islands during floods introduces new plants that colonize the island and usually displace the planted vegetation. Based on his observations, the use of expensive seed mixes on islands that will be overtopped or islands that aren't going to be managed to maintain the vegetation is questionable.

Table 9-7. Design Criteria for Earth Material Types and Vegetation on Islands

<table>
<tr><th>Design Discipline</th><th>Design Criteria</th></tr>
<tr><td>Geomorphology</td><td>5.a Topsoil thickness affects the vegetation communities and subsequently the hydraulic roughness of the island. Thicker topsoil layers will result in more woody vegetation creating a rougher surface during the annual flood, which usually occurs during the dormant season. This will reduce flow over the island and increase the potential for sediment deposition on the island. Lessons Learned 5.D.4</td></tr>
<tr><td rowspan="3">Engineering</td><td>5.b Topsoil thicknesses of 6 to 12 in are recommended to provide adequate coverage throughout the island. On lower islands (usually within 2 ft of the average water surface) 6 to 9 in is adequate. On higher islands, 12 in is recommended. Lessons Learned 5.D.1, 5.D.2, 5.H.1, 5.I.1; Habitat Parameter 4 (App. 9-B)</td></tr>
<tr><td>5.c Topsoil should consist of at least 40% fines (i.e. 40% of material passes 200 sieve), but not more than 70% fines. Coarse material is needed in the topsoil for infiltration. Anfang and Wege found that sites with more than 35% fines had a higher percent cover than sites with lesser amounts. Lessons Learned 5.D.2; Habitat Parameter 4 (App. 9-B)</td></tr>
<tr><td>5.d Topsoil placement should occur during the same construction season as granular fill placement to minimize the chance of erosion during Spring floods. The cohesive properties of topsoil help to stabilize islands during overtopping events. This is especially important since Anfang and Wege found that it may take 3 to 6 growing seasons before vegetation reaches a desired/maximum density. Lessons Learned 5.D.1, 5.H.1, 5.I.1</td></tr>
<tr><td rowspan="6">Constructability</td><td>5.e Fine sediments must be dried before construction equipment can be used to spread the material. Reference Lessons Learned: 7.A.2 7.C.2, 7.D.2, 7.H.3</td></tr>
<tr><td>5.f Use a maximum of 8-inches of fine sediment when disking with standard farm equipment. Habitat Parameter 4 (App. 9-B)</td></tr>
<tr><td>5.g The thickest layer of topsoil that has been placed with standard construction equipment is 4 ft - this is about the upper limit for constructability. Lessons Learned 7.C.3, 7.D.3, 7.H.2</td></tr>
<tr><td>5.h Topsoil and sand should be placed during the same construction season to minimize loss of sand due to wind or floods. Lessons Learned 5.D.1, 5.I.1</td></tr>
<tr><td>5.i Utilize sacrificial berm material for construction of temporary berms when placing topsoil hydraulically. Lessons Learned 5.H.2</td></tr>
<tr><td>5.j Minimize construction equipment travel over fine material to prevent soil compaction. Lessons Learned 5.C.3</td></tr>
<tr><td rowspan="4">Habitat</td><td>5.k Topsoil thickness depends on the types of vegetation desired. To maintain grasses and delay the conversion to woody vegetation, a thinner layer of topsoil should be placed on higher elevation sites. This prolongs the time that the island provides optimal conditions for ducks and grassland birds. The following table provides some guidance on topsoil thicknesses. Lessons Learned 5.A.2, 5.B.2, 5.C.1, 5.D.2; Habitat Parameters 4, 6(App. 9-B)
<table>
<tr><th>Vegetation Type</th><th>Topsoil Thickness</th></tr>
<tr><td>Shrubs , Trees</td><td>12” or greater</td></tr>
<tr><td>Grasses</td><td>6” to 12”</td></tr>
</table></td></tr>
<tr><td>5.l. Diverse, and thus more expensive native prairie seed mixes should not be used on lower sections of islands that will be frequently overtopped. In addition to competition with invasive species transported in by the river, woody vegetation will quickly become a problem. Once an island is overtopped, the planted seed mix is often overtaken by seeds carried by the river. Switchgrass seems to be one of the most aggressive and successful species and should be planted sparingly at sites where a diverse mix of grasses and forbs is desired. The seed mix should also include a legume species to replenish soil nitrogen levels to improve long term performance of plantings. Lessons Learned 5.A.3, 5.B.2, 5.C.1, 5.L.1</td></tr>
<tr><td>5.m Consider techniques to discourage grazing of new plants during the first few years after construction. Lessons Learned 5.J.1</td></tr>
<tr><td>5.n Rock sills should incorporate impermeable filter fabric if the sills are used as island features where overwintering habitat is an objective. Lessons Learned 5.H.3, 5.P.1</td></tr>
</table>

5. Design Considerations - Shoreline Stabilization. Table 9-8 lists design criteria for shoreline stabilization on islands. Since islands are constructed in areas where erosive forces have, in the past, caused islands or shorelines to erode, some form of shoreline stabilization is needed. At a few of the earlier projects (Weaver Bottoms, Swan Lake, and Peoria Lake) unprotected shorelines were severely eroded following construction. The primary forces that affect island shorelines are river currents and wind driven wave action, though ice action and waves created by towboats or recreational boats can also cause erosion.

One of the most common methods used to stabilize island shorelines is the construction of an earthen berm along the island shoreline which is usually stabilized with rock or wood structures such as groins, vanes, or offshore rock mounds. The berm, which is illustrated in the top cross section on figure 9-5 by dimensions "a" and "e," is usually 2 feet or less above the average water surface. The purpose of the rock structures is to prevent excessive erosion of the berm during normal flow conditions, while the primary purpose of the berm is to provide conditions for the growth of woody vegetation, which reduces wave action on higher parts of the island during floods. Although colonization by woody plants will occur naturally, sandbar willow is usually planted on berms to increase the rate of colonization. Within a few years, the willows usually spread to cover 20 or 30 feet of the berm and side slopes. Other species such as False Indigo and Willow hybrids have been used in smaller quantities. The berm must be wide enough so that even if woody vegetation density is not high, there is sufficient energy dissipation by the plant stems to protect the main portion of the island during high water. In most cases, after the berm is constructed, erosion of the outer portion of the berm due to wave action results in offshore transport of sand, which forms a gradually sloping beach with a 1V:8H to 1V:12H slope. The goal is to construct a wide enough berm so that after the beach building process is complete, at least 20-feet of berm remains as substrate for woody vegetation growth. Additional information on the design of these features can be found in chapter 5 of this handbook.

Riprap is usually used at the ends of islands which are exposed to wave action from more directions, are exposed to higher river currents in some cases, and have a convex shape which requires more earth material for beach building. Shorelines that are exposed to small wind fetch or have off-shore water depths that are very shallow, often can be stabilized with vegetation alone, with no need for rock structures (photograph D-6). Although there is significant variation from project to project, a typical distribution is 20 percent riprap, 40 percent biotechnical, and 40 percent vegetative. More recent projects tend to have less riprap and more use of bio-geo and vegetative stabilization. Additional information on shoreline stabilization can be found in Chapter 4 of this handbook.

Table 9-8. Design Criteria for Shoreline Stabilization of Islands.

Design Discipline	Design Criteria
Geomorphology	6.a Design for more dynamic shorelines that maintain a beach zone through littoral drift. If the shoreline is completely stable, terrestrial vegetation will encroach into the beach zone. Constructing unprotected sand tips or sand flats are techniques to soften the appearance of the islands and maintain a more dynamic beach zone. *Lesson Learned 6.D.1, 6.P.1, 6.Q.1*
Engineering	6.b Use information in Chapter 4, *Shoreline Protection*, of this handbook, Engineering Consideration 1 (Appendix 9-C), the Coastal Engineering Manual, and EM 1110-2-1601 to design shoreline protection. Some rules of thumb include: • The potential for shoreline erosion increases with water depth. Shorelines with offshore water depths less than 2 feet can be stabilized with vegetation. Those with offshore depths greater than 3 feet usually need rock structures. *Lessons Learned 6.A.1, 6.B.2, 6.C.2, 6.D.3, 6.H.3; Engineering Consideration 1 (App. 9-C)* • Extremely sheltered shorelines (those exposed to less than a 2000 foot wind fetch) should be stabilized with vegetation only. *Lessons Learned 6.A.4, 6.P.2, 6.Q.2; Engineering Consideration 1 (App. 9-C)* • Rock or wood structures must be constructed along island shorelines subject to wave action from wind fetches greater than 1-mile. Vegetation by itself will not stabilize a shoreline or embankment subject to sustained long-term wave action. *Lessons Learned 6.A.8, 6.B.3, 6.D.6, 6.J.1* • The elevation on rock structures decreases with time due to settlement or ice action. This should be taken into consideration in feature design and in the soil boring plan. *Lessons Learned 6.A.7, 6.E.1* 6.c Although berms as narrow as 20 feet have been used where minimal erosion was expected, 40 feet is the standard berm width. *Lessons Learned 6.D.1, 6.D.2, 6.P.3, 6.Q.3; Engineering Consideration 1 (App. 9-C)* 6.d A swath of woody plants at least 20 feet wide is needed along the island shoreline to provide rigid stems and protect the shoreline during floods. *Lessons Learned 6.D.1, 6.D.3, 6.H.2; Engineering Consideration 1 (App. 9-C)* 6.e If ice action is severe, flatten rock slopes to 1V:4H or flatter. *Lessons Learned 6.B.1; Engineering Consideration 1 (App. 9-C)*
Constructability	6.f Provide access to the site for trucks or barges hauling rock . Access can be at a single point on the island and rock moved to feature location. Truck traffic and placement of protection should avoid compacting fine material.
Habitat	6.g Create diverse shoreline habitat with littoral/riparian area that includes aquatic, beach, and terrestrial zones. 6.h Build sand flats and mud flats near islands in sheltered areas. 6.i Use larger stone size than required to provide better substrate for benthic organisms and fish. *Habitat Parameter 1(App. 9-B)* 6.j Include woody material (logs, stumps) in shoreline protection to provide loafing structure and shelter. Consider optimal wood types based on decay resistance and weight (heavier generally being better) *Habitat Parameter 2, 5 (App. 9-B); Engineering Consideration 7 (App. 9-C)*

6. Design Considerations – Construction. Islands in the northern reaches of the UMR are usually constructed with sand (granular fill) and mixtures of fine sediments and sand. The base of the island is constructed of sand to provide a stable work surface for construction equipment and then mixtures of fine sediments and sand are placed on top of the sand as random fill or as a fine material layer that acts as topsoil (photo D.3). Both hydraulic and mechanical dredging operations have been used successfully to transport sand and fine sediments to these projects. However for most recent projects, fines have been dredged mechanically and transported to the project site on barges. More recent projects have included mudflats and sand flats along the islands. These features serve the dual purpose of creating habitat and providing an area for dredge material to be placed.

Several island projects included an outside containment berm usually made of granular fill with in-situ sediment dredged from the adjacent backwater placed in the area contained by the berm. Examples of this type of construction include islands constructed at Bertom McCartney and Sunfish Lake in Pool 11. This type of construction technique results in very thick layers of random fill. A few island projects have been constructed by side casting dredge material from adjacent backwater dredging. Side cast islands include those at Swan Lake (1996) and Peoria Lake (1997) on the Illinois River, Mud Lake in Pool 11 and Tilmont Lake Peninsula (2002). One of the reasons for doing this is the desire to dredge backwater areas deeper. However, in some cases, it might just be that sand is not available to construct the sand base. The specifications for these projects called for the contractor to use a large bucket (e.g. 7 cubic yards at Peoria Lake) for mechanical excavation. This was done so that the fine sediments would be placed in larger masses, preserving some of the in-situ cohesive strength of the sediments and preventing fluidization. The side slopes of these islands were also flattened (1V:6H at Swan and Peoria Lake) to add more stability to the islands. The islands at Peoria Lake were constructed in 3 lifts. The Peoria Lake Island on the Illinois River, which will be completed by 2013, consists of geotextile containers filled with sediment. Another construction technique includes constructing a narrow island with rock fill. This was used for the Pool 9 Island project (1994).

The cost of several island projects, are shown in table 9-9. Based on the Pool 8, Phase III project the typical cost for earth islands is $460 per linear foot or $180,000 per acre of island. Many of the islands included additional habitat features such as mud flats, sand flats, turtle nesting mounds, and loafing structures, which added to project costs.

7. Lessons Learned. Many lessons have been learned during the design, construction, and maintenance of island projects. Documentation of these lessons learned is an important step in the adaptive management approach that has been ongoing since the first islands were constructed in the mid 1980s. Several major floods have occurred during the 25 years that the islands have been in existence, providing valuable information on project durability, maintenance requirements, and rehabilitation methods. Using lessons learned is an important aspect of habitat project design since the experience gained from past projects can be used to improve future designs. The following seven tables list lessons learned from previous projects. Tables 9-11 through 9-17 cover different design categories; table 9-17 shows lessons learned regarding constructability. The numbering system for the lessons learned is shown in table 9-10. The first number represents the design category or constructability; the letter represents the project (19 projects designated by the letters A through S); the final number represents the lesson learned for each project. Using this system, *1.B.1* would be used to designate Layout Category in Weaver Bottoms, Lesson Learned #1.

Table 9-9. Costs of Island Projects

Project	Year Constructed	Feature	Length (ft) Area (ac)	Cost	Cost/ft Cost/ac
Pool 8, Phase I, Stage 2	1992	Earth Islands	9,600 ft	$1,456,000	$151/ft
Pool 8, Phase II	1999	Earth Islands	10,600 ft	$1,755,000	$165/ft
		Rock Sills	2,500 ft	$722,000	$288/ft
		Seed Islands	1,280 ft	$169,000	$132/ft
		Total Cost		$2,646,000	
Polander Lake, Stage 2	2000	Earth Islands	9,200 ft	$1,897,000	$206/ft
Sunfish Lake, Pool 11[1]	2003	Earth Islands	8,724 ft	$3,972,600	$455/ft
Spring Lake, Pool 5[1]	2005	Earth Islands	10,065 ft 20.3 ac	$3,078,000	$305/ft $151,600/ac
Mud Lake, Pool 11[1]	2005	Earth Islands	10,804 ft	$3,482,919	$322/ft
Pool 8, Phase III, Stage 1	2006	E1 (cobble) E2 (log/rock) E3 (sand)	600 ft 760 ft 1,151 ft	$303,000 $147,000 $255,000	$505/ft $194/ft $221/ft
Pool 8, Phase III, Stage 2B, Islands W1, W2, W3, W4, N7, N8[1]	2008	Earth Islands	23,600 ft 58 ac	$10,329,000	$437/ft $178,000/ac
Pool 8, Phase III, Stage 3A, Islands C2, C3, C4, C5, N2[1]	2010	Earth Islands	10,126 ft 42.5 ac	$4,681,000	$462/ft $150,000/ac
Pool 8, Phase III, Stage 3A, Islands C2A, C2B, C2C	2010	C2A (seed I) C2B (seed I) C2C (log/rock)	200 ft 220 ft 160 ft	$53,900 $61,800 $40,500	$270/ft $281/ft $253/ft
Pool 8, Phase III, Stage 3B, Islands C6, C7, C8[1]	2011	Earth Islands	7,160 ft 17 ac	$3,360,000	$469/ft $198,000/ac

[1] Costs per foot and cost per acre were obtained from the USFWS.

Table 9-10. Key to Numbering Systems in Tables 9-11 Through 9-17

Category	Project	Lesson Learned
1. Layout 2. Elevation 3. Width 4. Side Slope 5. Topsoil &Vegetation 6. Shoreline Stabilization 7. Constructability	A. Weaver Bottoms B. Lake Onalaska C. Pool 8, Phase I, Stage 1 D. Pool 8, Phase I, Stage 2 E. Pool 9 F. Polander Lake, Stage 1 G. Willow Island, Pool 10 H. Pool 8, Phase II I. Polander Lake, Stage 2 J. Swan Lake, Illinois River K. Spring Lake, Pool 5 L. Peoria Lake, Illinois River M. Bertom McCartney N. Pool 11 Islands O. Pool 8, Phase III, Stage 1 P. Pool 8, Phase III, Stage 2 Q. Pool 8, Phase III, Stage 3 R. Peoria Island, Illinois River S. Capoli Slough	1. Lessons learned are listed numerically for each project 2. ……….. 3. ………..

Table 9-11. Lessons Learned, Design Category 1 – Island Layout

Project (Year Constructed)	Lessons Learned
Weaver Bottoms (1986)	1.A.1 Islands that shelter shallow water areas increase the aquatic vegetation response in those areas. Swan and Mallard Islands sheltered primarily deep areas (e.g. depths greater than 3') and produced a limited aquatic vegetation response in those areas. Several sheltered bays were created by this island layout; however, the only significant vegetation response occurred in the shallow portion of the southernmost bay of Mallard Island. 1.A.2 Islands in deep water have high erosion rates. The deep water these islands were placed in resulted in excessive shoreline erosion due to the amount of sand transported offshore during beach building. 1.A.3. The positioning of the islands near the Whitewater Delta and near side channels may have promoted delta expansion due to wave action reduction which reduced delta erosion.
Lake Onalaska (1989)	1.B.1 Low velocity deposition zones were created both upstream and downstream of Arrowhead island, while high velocity erosion zones were created to either side of the island (USGS-UMESC, Biological Response Study, Lake Onalaska). By positioning islands perpendicular to the primary flow path, the size and magnitude of these zones was increased. 1.B.2 By positioning islands perpendicular to the primary wind direction, the size of the downwind sheltered zone was maximized. 1.B.3 Islands provide suitable habitat and offer protection to: 1) Macrophytes (if water depths are three ft or less), 2) Fish for use as a nursery area, 3) Finger Nail Clams, and 4) Diving ducks that fed on the Finger Nail clams. (Based on USGS, Biological Response Study, Lake Onalaska). 1.B.4 Islands isolated from human disturbance provide more waterfowl nesting opportunities. Broken Gun Island, which experiences significantly more human disturbance than Cormorant or Arrowhead Islands, had a much lower nesting success rate than either of the other two islands. 1.B.5 Vegetation sampling done by the WDNR at Arrowhead Island in 1997 documented the presence of extensive aquatic vegetation beds along the shallower (depth < 3') western half of the island corresponding to the downstream shadow zone. The vegetation response along the deeper eastern half of the island was not as good. 1.B.6 Islands in deep water have high erosion rates. The deep water that portions of these islands was placed in resulted in excessive shoreline erosion due to the amount of sand that was transported offshore during beach building. A wider berm should have been used in order to provide additional sacrificial material for beach establishment (see Engineering Consideration 6, Appendix 9-C, for a description of the beach formation process). As of 2012, these islands are relatively stable, though some erosion was observed during recent flood events.
Pool 8, Phase I, Stage I, Horseshoe I (1989)	1.C.1 The shallow off-shore water depths along portions of this island eliminated the need for rock protection. 1.C.2 Placement of islands a distance back from the navigation channel (100 to 300 ft) allowed for shallow water depths to dampen wave action before reaching the berm of the island, therefore reducing the need for additional bank stabilization.
Pool 8, Phase I, Stage II Boomerang Island (1992)	1.D.1 The shallow off-shore water depths (less than 1 foot deep) along portions of this island eliminated the need for rock protection. 1.D.2 The design team did an on-site inspection of the project layout before finalizing plans and specs. The centerline of Boomerang Island was staked and inspected, resulting in several adjustments that improved island position and avoided changes during construction. 1.D.3 Access channel dredging accounted for a significant percentage of the fine material placed on the island, reducing beneficial backwater dredging. Several of the access channels at Boomerang Island exceeded 500' in length. 1.D.4 Placement of islands a distance back from the main channel allowed for shallow water depths to dampen towboat and recreation boat waves before reaching the berm of the island, therefore reducing the need for additional bank stabilization. 1.D.5 Shortly after construction, deposition was observed along the north south leg of Boomerang Island. Although deposition had been observed at Heron and Trapping Islands just downstream, it appeared that Boomerang Island changed the patterns of deposition so that less sand was being deposited in the backwaters. The deposition occurring in the Heron and Trapping Islands area was the catalyst to the development of seed islands constructed by the agencies under separate funding and later as part of Pool 8 Islands, Phase II.
Pool 9 Islands (1994)	1.E.1 Field surveys of the hydraulic conditions in the project area improved the final design. The initial plan was to build islands to prevent the inflow of water and sediment from the main channel. Hydraulic surveys determined that flow in this area was actually from the backwater to the main channel and that wave action from the downstream direction was significant. This led to the inclusion of an island to reduce wave action from the south. 1.E.2 Restoring sheltered floodplain conditions resulted in significant growth of aquatic vegetation in the shallow interior area (less than 3 ft deep) sheltered by these islands. These islands were laid out so that wind fetch from the northwest and southeast was reduced to less than 4,000 ft, compared to the pre-project wind fetches of over 10,000 ft. The inflow to this area from the backwater was also reduced.

Table 9-11. Lessons Learned, Design Category 1 – Island Layout

Project (Year Constructed)	Lessons Learned
Pool 8, Phase II Stoddard Bay Islands (1999)	1.H.1 Several island remnants existed along the alignment of the new islands. Rather than covering them up, the island alignment was adjusted so that the remnants would become part of the berm or would be located just offshore of the berm resulting in improved aesthetics and reducing erosion of the new island shoreline. 1.H.2 The criteria for backwater fish resulted in increases in fish population in Stoddard Bay (WDNR data). The objective was to create 200 acres of over-wintering habitat meeting the following criteria: Dissolved Oxygen levels > 3 mg/L Current velocity < .01 fps over 80%of area Water temperatures – 4°C over 35 % of area, 2-4° C over 30 % of area, 0-2° C over 35% of area. Water depths > 4 ft over 40 % of the area. 1.H.3 Restoring sheltered floodplain conditions resulted in significant growth of aquatic vegetation in the shallow interior area (less than 3 ft deep) bounded by these islands. The outer barrier islands reduced flow velocities in the shallow areas to less than 0.1 fps during the growing season and reduced wind fetch from the north and west to less than 4,000 ft. The interior islands were positioned to protect the shallow areas from southerly winds, reducing wind fetch from the south to less than 4,000 ft, compared to the pre-project wind fetches of over 10,000 ft. 1.H.4 Two-dimensional hydraulic modeling played an important role in determining the final island layout. Rock sill dimensions and interior island locations were adjusted based on model results. 1.H.5. Sill heights were determined based on a balance between maximizing flood conveyance through Stoddard Bay, which would keep sill elevations low; and minimizing the occurrence of overtopping events during the critical over-wintering months of November to March, which would keep elevations high. The elevation chosen limited November to March overtopping to 1 yr in 10. So far this seems to have been a reasonable design criteria. 1.H.6 The affects of ice cover on velocity was estimated, based on the decrease in conveyance area that would occur from 2 ft of ice, resulting in a change to the cross-section of the notch in upper rock sill. WDNR monitoring indicates that the design goal of 50 cfs has been achieved.
Polander Lake, Stage 2 (2000)	1.I.1 Several isolated wetlands or bays were created as part of this layout to shelter the shallow interior area. The best response from vegetation, particularly emergents in the isolated wetlands, was at Interior island No. 1, which had fines pumped into it to reduce the 2.5 to 3 foot water depths to about 1 foot. Water depths within the three other isolated wetlands were in the 2 ½ - 3 foot range which is too deep for emergents except on the margins. However, floating-leaved aquatics like lotus and water lilies responded positively throughout the complex.
Spring Lake Islands (2005)	1.K.1 The downstream end of Snipe Island, is located near a deeper channel and experienced more scalloping between vanes than anticipated. This was a narrower section of the island which increased concern that a breach might form across the island. However, overtopping floods in 2010 and 2011 did not result in a breach. 1.K.2. Incorporation of mudflats as part of all islands increased habitat diversity and capacity for material dredged from backwaters. The mudflats quickly colonized with emergent vegetation.
Pool 8, Phase III, Stage 2	1.P.1 Islands were laid out to create multiple habitat areas with the vegetated islands acting as visual barriers to minimize disturbance to waterfowl. 1.P.2 Historic aerial photography and existing conditions bathymetry collected with funds from the EMP – LTRM were used to lay out islands along the shallow areas (i.e. Natural levees/islands) adjacent channels. This resulted in cost savings since these are generally the shallowest areas, and better foundation conditions since these areas were preloaded by islands that had since eroded. 1.P.3 A two dimensional numerical model was used to finalize island positions.
Pool 8, Phase III, Stage 3	1.Q.1 Islands were laid out to create multiple habitat areas with the vegetated islands acting as visual barriers to minimize disturbance to waterfowl. 1.Q.2 Historic aerial photography and existing conditions bathymetry collected with funds from the EMP – LTRM were used to lay out islands along the shallow areas (i.e. Natural levees/islands) adjacent channels. This resulted in cost savings since these are generally the shallowest areas, and better foundation conditions since these areas were preloaded by islands that had since eroded. 1.Q.3 A two dimensional numerical model was used to finalize island positions.

Table 9-12. Lessons Learned, Design Category 2 – Island Elevation

Project (Year Constructed)	Lessons Learned
Weaver Bottoms, Pool 5 (1986)	2.A.1 High islands take a long time to be colonized by woody vegetation (Anfang and Wege, 2000). In Weaver Bottoms, this is partly due to management efforts to maintain native prairie grasses on Swan Island through periodic burning. However, Mallard Island, which was not planted to prairie grasses, has not been colonized by woody vegetation either. These islands have a top elevation approximately 8 ft over the avg water surface. 2.A.2 Low elevation berms (less than 2 ft above avg water surface) that formed along portions of Swan Island during construction were rapidly colonized by woody plants. This did not occur elsewhere on either of the islands. Berms were not included in the design and formed accidentally in only a few locations due to site conditions.
Lake Onalaska (1989)	2.B.1 The high elev of these islands (6 ft over avg water surface) combined with periodic burning has maintained the islands' native prairie grasses delaying the conversion to woody vegetation. USFWS personnel (Nissen, pers. com.) feel higher elev is primary factor because fuel load on these islands is insufficient to create a fire hot enough to kill woody vegetation. 2.B.2 The higher elevation berms (approximately 3 ft over the avg water surface) delayed colonization of woody vegetation. Because of the excess dredge material, the berms on the Lake Onalaska Islands were constructed approximately 1 foot higher than the design elevation. This may have been one of the reasons that colonization by woody vegetation took a longer time.
Pool 8, Phase I, Stage I, Horseshoe Island (1989)	2.C.1 High islands take a long time to be colonized by woody vegetation. The northern section of Horseshoe Island is retaining its grass cover and not converting over to herbaceous and woody vegetation. The as-built elevation of the west leg of this island is approximately five ft above the avg water surface elevation Soil compaction by construction equipment may have also been a factor reducing the conversion to woody vegetation. 2.C.2 Significant portions of backwater side of this island were less than 2 ft over the avg water surface. Dense woody vegetation growth occurred on these areas right down to pool level.
Pool 8, Phase I, Stage II Boomerang Island (1992)	2.D.1 Islands less than 5 ft above the avg water surface elevation are more likely to convert to herbaceous and woody vegetation. Boomerang Island was constructed to an elevation of approximately 4.5 ft above the avg water surface elevation. This island rapidly converted over to woody vegetation. 2.D.2 Islands constructed to lower elevations are not exposed to severe erosive forces associated with floods as long as there is not a significant head differential across them. Grassy Island was constructed to an elevation of 633.0 (5-yr flood elevation). During the 1993 flood (approximately a 15-yr event) measurements over the top of this island indicated velocities less than 2 fps. In addition, wave action had no effect on the island due to the fact it was submerged by 3 ft of water. 2.D.3 The berms on Boomerang Island sloped from 2 ft over the avg water surface where the berm attached to the main part of the island, to 0.5 ft over the avg water surface at the outer edge. Dense vegetation growth occurred on these berms right down to the pool level. 2.D.4 Along the longitudinal profile, top elevations were decreased to match the water surface elevation. A 500' reach at the upstream end of the project had a top elevation of 636. The elevation decreased to 635.0 over the next 2200 ft, and finally to 634.8 for the lowest 5900 ft. This may have been one of the factors that have limited erosion during floods, however there are several reaches of the island that have apparently settled and are overtopped before the rest of the island. 2.D.5 In several reaches, sand deposits during flood events have increased the top and berm elevations.
Pool 9 Islands (1994)	2.E.1 Islands constructed to lower elevations are not exposed to the severe erosive forces associated with floods. These islands, which consisted of rock mounds, have been overtopped numerous times and show minimal damage from overtopping, though some low spots have developed due to long-term settlement of the rock, ice action, or blind building by hunters.
Pool 8, Phase II, Stoddard Bay Islands (1999)	2.H.1 The low rock sills combined with a stepped down island design resulted in a stable project during the 2001 flood, when the islands were less than 2 yrs old and didn't have well established vegetation. The rock sills were set at the lowest elevation, since they can withstand the erosive forces that typically occur during the initial stages of overtopping. Island elevations decrease in the downstream direction so that after the rock sills are overtopped, the furthest downstream section of earth island is overtopped first, then the next section, and the next in a stair-step fashion, etc. As each section of island is overtopped, it reduces the head differential on the next upstream section. 2.H.2 Islands constructed to lower elevations are not exposed to the severe wave action that occurs during floods; these islands overtopped during 2001 flood ; minimal damage occurred. 2.H.3 Higher sections of island are exposed to higher erosion rates due to river currents and wave action. During floods, wind fetch increases significantly because lower features in the backwaters, that normally break up wind fetch are now submerged. In addition, current velocities reach a maximum in backwaters during floods and any feature that redirects flow (like an island), causes currents to accelerate resulting in erosion at the edge of the feature. The features constructed to higher elevations were severely eroded during the 2001 flood. Sand humps were included in this project to provide bare sand habitat for turtles; these humps varied in elevation from 636 to 638 (or 1 to 3 ft higher than the highest island section). The 2001 flood had a long crest with twin peaks, resulting in water surface elevations of 636 to 638 for up to 2 weeks. During this time wave action and river currents eroded all of the humps to some extent, with 1 completely scoured out to below pool elevations (629 to 630). The 2 sand humps on Slingshot Is. most severely eroded were downstream from one of the rock sills and may have been exposed to higher river currents. The typical sections of islands that varied in elevation from 633 to 635 were stable.

Table 9-12. Lessons Learned, Design Category 2 – Island Elevation

Project (Year Constructed)	**Lessons Learned**
Pool 8, Phase II, Stoddard Bay Islands (1999) - ***continued***	2.H.4 During construction of the interior islands, the contractor discovered that excess material had been stockpiled on one of the islands. The design team decided that the excess material should be used to widen the berm and extend the length of the island. This would preserve the desired island elevations which were based on habitat considerations. 2.H.5 The rock sills are not overtopped as frequently as was expected, however the habitat response has been good and monitoring is being done to assess geomorphic response. 2.H.6. During an extended low water period during 2011, algae production was excessive, causing significant complaints from the public to the project sponsor, the USFWS.
Spring Lake islands (2005)	2.K.1 The combination of Island 1 having a low elevation and the material under the island being soft, caused poor foundation conditions for the equipment resulting in equipment frequently getting stuck. A higher elevation would have displaced more of the soft substrate due to the additional weight.
Pool 8, Phase III, Stage 2 (2008)	2.P. 1 Emergent wetland elevations varied up to 2 ft, with the mean elevation being 0.5' below the avg water surface elevation during the waterfowl migration season. The high spots that occur at the dredge pipe discharge point can be above the avg water surface. The dredge pipe should be moved frequently during placement of dredge material resulting in an undulating surface. The elevations of the emergent wetland on Broken Bow Island resulted in the best quality wetland of the three emergent wetlands that were constructed as part of this project. This was due to the fact that this was the third emergent wetland constructed as part of this project stage, and using lessons learned from the previous two, the USFWS was better able to communicate to the contractor the preferred avg and variation in elevation.

Table 9-13. Lessons Learned, Design Category 3 – Island Width

Project (Year Constructed)	Lesson Learned
Weaver Bottoms, Pool 5 (1986)	3.A.1 Wider islands create more contractor flexibility when constructing the islands. These islands had a 100' top width, and 1V:4H side slopes, giving them an extremely large footprint (over 160'). This extremely large size was a benefit during construction since the contractor was able to create large containment cells on the island, into which fine sediments were hydraulically dredged and allowed to dry. These fine sediments were then spread over the island as topsoil. 3.A.2 A large top area, combined with steep side slopes, may result in gully erosion on the side slopes of the islands due to local runoff. Gullies formed on the side slopes of both Swan and Mallard Is. due to rainfall runoff. Though not a major problem, some attempts were made to stabilize the gullies. This has not occurred on other island projects.
Lake Onalaska (1989)	3.B.1 Berm width on these islands should have been wider than the 20 ft specified in the design. The deep water (greater than 3-ft depths) that portions of these islands were placed in resulted in excessive shoreline erosion due to the amount of sand that was transported offshore during the beach building process. In some cases almost the entire berm was eroded.
Pool 8, Phase I, Stage I Horseshoe I (1989)	3.C.1 Large dredges result in islands with a large footprint. The Dredge Thompson was used to place the granular fill for this island. The dredge plume from this large dredge caused sand to spread out forming a gradually sloping island cross section over 150' wide in some cases. Terrestrial vegetation rapidly colonized this section of island.
Pool 8, Phase I, Stage II Boomerang Island (1992)	3.D.1 Berm width on these islands was 30 ft in most cases. This was adequate over 95%of the shorelines, however there were a couple of reaches along the main channel where the combination of wave action and river currents caused excessive erosion. Remedial stabilization was required at these sites. 3.D.2 In several reaches of Boomerang Is. the berm width was reduced to 20 ft. These reaches either had shallow offshore water depths (less than 2 ft deep), protection from aquatic vegetation, protection from existing islands, or some combination of the above. The 20 foot berm was adequate at these sites.
Pool 9 Islands (1994)	3.E.1 Narrow islands constructed of rock alter hydrodynamic conditions as well as earth islands. The Pool 9 islands had a 5 foot top width and side slopes as steep as 1V: 1.7H, resulting in a very small footprint. They reduced wave action and river currents in the project area. 3.E.2 Rock mounds, capped with adjacent borrow where used to mark the island so boaters would have some reference as to location of rock islands when overtopped. Top dressing of soil eroded away within a yr and several of the rock mounds have been knocked down by either ice action, or due to construction of hunting blinds with the mound.
Willow Island (1995)	3.G.1 The majority of this island was stable during the 1997 and 2001 floods, however, a couple of small breaches did form in 1997. The total width of this island including side slopes and berms was over 80'.
Pool 8, Phase II, Stoddard Bay Islands (1999)	3.H.1 Berm width on these islands was 30 ft in most cases. This was adequate over 95% of the shorelines, however there were a couple of reaches along a large secondary channel where the combination of wave action and river currents caused excessive erosion. Remedial stabilization was required at these sites. 3.H.2 Rock sill top widths set at 13' in case scour hole developed downstream of rock sill. The thought was that if scour started undermining downstream toe, the sill would be wide enough for some self-healing. But, reconnaissance shows scour hasn't occurred at these sills (photo H.15, App 9-A). Rock sill top width could have been 10' and perhaps less. 3.H.3 Burrowing activities by Muskrats and subsequent collapse of the tunnels, has resulted in occasional depressions extending from the island shoreline towards the center of the island. The concern here is that a continuous tunnel through the island could create a low spot that might erode during an overtopping event. However, in all cases, these tunnels are less than 20' long so they don't create a problem in the 30' to 50' top width islands used at this project.
Polander Lake (2000)	3.I.1 The majority of these islands were stable during the 2001 flood, however, a breach did form, and small areas of erosion were observed. The erosion was probably due to the fact that these islands were constructed the previous yr and had not been vegetated yet. While the top width of these islands was only 20', the overall footprint of these islands was fairly typical because they had flat side slopes of 1V:5H, and berms that varied from 30 to 40 ft in width.
Spring Lake Islands (2005)	3.K.1 The contractor found it difficult to contain the dredge plume and maneuver equipment on Water Snake Is. because of its narrow width and their construction method which included the use of a large 22" hydraulic dredge. In addition, some of the dredge material ended up being placed outside the footprint of the island. This island was designed with a top width of 20 ft, to reduce the size of the island footprint. A 40-ft width would have resulted in better maneuverability for the contractors chosen method of operation. 3.K.2 Downstream end of Snipe is located near a deep channel, experienced more scalloping than anticipated due to wind-driven wave action. This was a tapered section of the island and narrower width increased concern that a breach might form across it. If section had been wider, or moved further from the deeper channel, concern wouldn't have been so great.
Pool 8, Phase III, Stage 2	3.P.1 Several breaches have formed in island N1, which was a narrow island with a top width of 40 ft. These breaches occurred during overtopping flood events. This seems to indicate that island width should have been greater than 40 ft for increased stability. 3.P.2 Middle section of island W2 (renamed Raft Island) was constructed at elev 632.0 (NGVD 1912)-lower than the adjacent sections of islands. Since island would be overtopped first during a flood event, the overall width was increased to 162 ft, which is about 30' wider than other islands along Raft Channel. Increased width resulted in a stable island.
Capoli Slough, Stage 1 (2012)	3.S.1 For economic constructability w/ mechanical placement of earth material, islands should be at least 35 ft wide. For hydraulic placement, islands usually need to be at least 100 ft wide. 3.S.2 Rock sills A & E increased to top width of 25 ft (from normal 10' width) to provide access to adjacent islands for construction equipment. Contractor used these sills for access.

Table 9-14. Lessons Learned, Design Category 4 – Side Slope

Project (Year Constructed)	**Lesson Learned**
Weaver Bottoms, Pool 5 (1986)	4.A.1 Side slopes of 1V:4H or steeper may develop gullies if the local drainage area is large enough to produce significant runoff. Gullies formed on the side slopes of both Swan and Mallard island due to rainfall runoff. This was not a major problem, however some attempts were made to stabilize the gullies with small hand-built check dams. This problem has not occurred on other island projects. 4.A.2 Wave action quickly erodes and reshapes island shorelines, creating a beach with a flat slope (1V:8H to 1V:15H). This occurred on all of the shorelines exposed to wind fetches of a few thousand ft or more. Reshaping began immediately after construction.
Lake Onalaska (1989)	4.B.1 Gullies did not develop on side slopes of 1V:5H. However this may be due to the smaller local drainage area created by the 50-foot top width on the Lake Onalaska Islands compared to the 100 foot top width on the Weaver Bottoms Islands. 4.B.2 Portions of the 1V:3H riprap slopes at these islands were severely damaged when ice action pushed the toe of the rock slopes in, reshaping them to a steeper slope and leaving geotextile exposed. This was repaired by adding new rock at a flatter 1V:4H slope to cause future ice to deflect up and break rather than shoving the riprap. In addition, the greater quantity of rock that results with flatter slopes, allows for self-healing of riprap. Some rock movement has occurred with the flatter slopes, however this has not required further repair. The use of larger rock was considered, however research by the U.S. Army Corps of Engineers Cold Regions Lab (Sohdi, 1997) indicates that rock size must be 2.5 times the ice thickness to minimize the chance of movement. Since ice on Lake Onalaska reaches a thickness of 30 inches, the stone size would be exceptionally large and require special handling techniques.
Pool 8, Phase I, Stage I Horseshoe I (1989)	4.C.1 Hydraulic placement of sand in shallow water results in a relatively flat slope as the dredge slurry spreads out. In one section this resulted in a significant amount of aquatic habitat being covered up. Some of this sand was later recovered using a backhoe.
Pool 8, Phase I, Stage II Boomerang (1992)	4.D.1 Gradually sloping the berms results in elevation diversity and rapid colonization by woody vegetation. The top elevation of the berms varied from 632.5 to 631.0 resulting in slopes of 1V:13H to 1V:20H for the 20 and 30 foot wide berms that were used on this project. These berms were rapidly colonized by woody vegetation. 4.D.2 Wave action quickly reshapes the slope of berms, creating a beach with a flat slope (1V:8H to 1V:15H). On the long north-south leg of this island, where groins were placed, wave action reshaped the berms, which had been constructed at a 1V:20H slope. This begins immediately after the berms are constructed and most of the reshaping occurs during the same yr they were constructed. This brings into question whether constructing a berm with a slope is worth the extra effort as compared to simply constructing a horizontal berm. The slope of the ends of the berms was the angle of repose for this project, however experience suggests that specifying an end slope on the berm, and subsequently defining the island footprint is better from a construction standpoint.
Pool 9 Islands (1994)	4.E.1 Steep rock side slopes are stable. The design side slope of these rock islands was as steep as 1V:1.7H. 4.E.2 Rock mounds constructed to mark the islands during overtopping events were not stable, perhaps due to elevation above water and cone shape with xv:xH side slopes.
Swan Lake, Illinois R. (1996)	4.J.1 The flat 1V:6H side slopes improved the constructability and stability of these islands, which were constructed using fine sediments.

Table 9-15. Lessons Learned, Design Category 5 – Earth Material Types and Vegetation

Project (Year Constructed)	Lesson Learned
Weaver Bottoms, Pool 5 (1986)	5.A.1 Beaver activity can reduce the density of woody vegetation on islands. Although, not a significant impact on island stability, beavers removed a number of trees that were growing on Swan Island. 5.A.2 High islands delay the conversion from grassy to woody vegetation. Mallard and Swan Islands are both 8-ft above the avg water surface (80-yr flood level) and both islands are dominated by grasses. 5.A.3 The seed mix used on high islands like Swan and Mallard is important. Swan Island, which was planted, continues to produce good growth of native grasses. Mallard Island, which had topsoil placed on it, but was not seeded, hasn't produced quality grassland habitat.
Lake Onalaska (1989)	5.B.1 Supplemental fertilizing may be necessary to maintain vegetation. 5.B.2 High islands delay conversion from grassy to woody vegetation. The Lake Onalaska Islands are 6-ft above the water surface (20-yr flood level) and are dominated by grass, though conversion to woody vegetation is occurring. Periodic burning may have delayed succession, however discussions with USFWS staff indicate that the fuel supply on these islands was insufficient to create a hot enough fire to kill woody vegetation.
Pool 8, Phase I, Stage I Horseshoe I (1989)	5.C.1 High islands delay the conversion from grassy to woody vegetation. The west leg of Horseshoe Island is 5 to 6 ft above the avg water surface(10-yr flood level) and has retained its grassy vegetation longer than the East leg which was about a foot lower. 5.C.2 Sand placed for formation of the island base was left bare over the winter prior to fine placement the following spring. Significant wind driven sand erosion occurred and was deposited on ice in adjacent backwater. When the ice melted, the sand caused some loss of depth in the protected backwater. Sand should not be left bare for long periods of time without being stabilized against wind, wave or current induced erosion forces. 5.C.3 Soil compaction may have also contributed to reduced coverage of woody vegetation.
Pool 8, Phase I, Stage II Boomerang (1992)	5.D.1 Topsoil with cohesive properties provides significant erosion resistance and is a critical factor affecting island stability during overtopping floods for the first two yrs after construction, while terrestrial vegetation is becoming established. Boomerang and Grassy Island were stable during the 1993 flood even though the grass that was growing on the island was less than 2" tall and was still in "rows" left by the drill seeding technique when the island was overtopped. 5.D.2 A thicker layer of topsoil may promote the conversion from grasses to woody vegetation. Boomerang Island, which has up to a 48-inch layer of topsoil, quickly converted from grassy to woody vegetation. The avg gradation of topsoil on this island, based on 5 samples, was as follows: 61%clay, 27%silt, and 12%sand. 5.D.3 The activity of birds and mammals that graze on vegetation can impact density. The density of woody vegetation on Boomerang Island was very high within 5 yrs of project construction, however it was greatly reduced from yr 5 to 10 due to rodents girdling and killing the trees. 5.D.4 Following several flood events, a significant amount of sediment deposition has been observed on and adjacent to Boomerang Island. This island is adjacent to the main channel.
Pool 8, Phase II, Stoddard Bay Islands (1999)	5.H.1 Sand without a topsoil covering will erode during overtopping events. Several experimental turtle nesting mounds were included in the project. Because bare sand is needed by nesting turtles, topsoil had not been placed on the mounds. One of these mounds was completely eroded during the 2001 flood, and all suffered some erosion. Some of this erosion may also have been due to the positioning of the sand humps in line with project features designed to promote scour. 5.H.2 The full width of the islands including the berms (a width of 120 to 150 ft) was used to build temporary containment berms so that fine sediments could be hydraulically placed on the islands. 5.H.3 An impermeable geotextile membrane imbedded with the rock sills effectively eliminated seepage through the sills.
Polander Lake (2000)	5.I.1 Topsoil with cohesive properties provides significant erosion resistance and is a critical factor affecting island stability during overtopping floods for the first two yrs after construction, while terrestrial vegetation is becoming established. The Polander Lake Islands were constructed in 2000 and were overtopped during the 2001flood before any vegetation had become established. Island erosion was minimal. 5.I.2 Based on 2004 field reconnaissance, shrub plantings were successful, with Red-osier dogwood plantings doing very well. The success of tree plantings was variable and may be a function of drought conditions that occurred the summer after planting, or perhaps was due to a less thick layer of topsoil, or both. Green ash was the most successful, with silver maple making the poorest showing. The drier conditions found on the tops of the 5 foot high islands were identified as a factor affecting tree growth. Willow is colonizing the lower portions of the islands and is beginning to encroach on areas designated as turtle nesting habitat and is crowding some of the shrub plantings. This will require some control efforts.

Table 9-15. Lessons Learned, Design Category 5 – Earth Material Types and Vegetation

Project (Year Constructed)	Lesson Learned
Swan Lake, Illinois R. (1996)	5.J.1 Grazing by waterfowl destroyed much of the vegetation that was initially planted on the islands. Protection of the vegetation with bird netting or other techniques would have improved vegetation cover.
Peoria Lake, Illinois R. (1996)	5.L1 Natural colonization of the island by vegetation, resulted in grass being eliminated completely from the planting plan Plantings of arrowhead, bulrush, and willow matting were also reduced. 5.L.2 Arrowhead and Bulrush plantings failed due either to high water or grazing by Grass Carp.
Pool 11 Islands	5.N.1 Sunfish and Mud Lake embankments were both constructed with mechanically dredged fine material. The unprotected 5V:1H and 4V:1H side slopes are being damaged from wave action and muskrat burrowing. The “slow-no-wake” zone within Mud Lake appears to have helped reduce wave damage. Unable to get a “slow-no-wake” zone within Sunfish Lake.
Pool 8, Phase III, Stage 2 (2008)	5.P.1 Chinking material was placed on the upstream side of the Island N8 (now named Snake Tongue Island) rock sill to prevent seepage of water through the sill, which would affect overwintering fish habitat. However, preliminary field data collected in the winter of 2012 indicates colder than desired water temperatures in the interior of Island N8. This suggests that either seepage is occurring through the sill or an eddy at the downstream end of the island is introducing cold water. More data is needed.
Pool 8, Phase III, Stage 3 (2010)	5.Q.1 Willow plantings out of season rarely work unless water is available. 5.Q.2 It would be helpful if some borings were obtained after project features were designed, to make sure the borrow source has material meeting specifications. The Middle Slough granular fill borrow source had too much unsuitable over-burden for it to be usable. 5.Q.3 Use existing placement sites and dredge cuts for granular fill where possible to achieve cost savings for both the EMP and O&M. 5.Q.4 Willows planted in August did not survive, requiring that they be replanted the next spring. The contractor had requested a variance from the normal planting window, which ends on June 15.
Pool 8, Phase III, Stage 3 (2011)	5.Q.5 Assure that there are adequate sources of fill material readily available. The Middle Slough granular borrow site ended up being unusable, however additional borrow sites were quickly found in the main channel. 5.Q.6 Topsoil thickness on this project varied from 6 to 9 inches on lower islands to 12 – inches on higher islands. 5.Q.7 The quality of fine material can greatly affect the time and quality of establishment. Fines for this project were from Stoddard Bay sediment and provided an excellent topsoil material on the three islands C6, C7, and C8.

Table 9-16. Lessons Learned, Design Category 6 – Shoreline Stabilization

Project (Year Constructed)	Lesson Learned
Weaver Bottoms, Pool 5 (1986)	6.A.1 Islands in deep water have a high rate of shoreline erosion if they are exposed to erosive forces. The deep water these islands were placed in resulted in excessive erosion due to the amount of sand that was transported offshore during the beach building process. 6.A.2 Littoral drift (i.e. the transport of sand along a shoreline due to wave action) will occur on shorelines exposed to wave action. Groins successfully eliminated littoral drift. 6.A.3 The construction sequence delayed the application of shoreline stabilization on Swan and Mallard Islands by 2 to 4 yrs after construction. This resulted in some erosion, but the rock volumes were reduced because the stabilization could be placed on the shallow beach that formed. In addition, stabilization could be selectively placed on only shorelines that were eroding, resulting in less than half of the shoreline length being stabilized. 6.A.4 Shorelines exposed to more than 1 mile of wind fetch will erode, though extremely shallow off-shore water depths or extensive aquatic vegetation may reduce erosion. Over half of the outer shorelines of Mallard and Swan Islands eroded significantly. The shorelines in the bays, where wind fetch was typically less than 1000 ft, eroded very little. These islands should have been designed with sacrificial material that could be eroded into the beach zone. 6.A.5 Convex shorelines (e.g. island tips) eroded at a faster rate than the straight or concave shorelines. This was because the offshore beach area is larger on a convex shoreline than it is on a straight or concave shoreline. 6.A.6 A low elevation berm placed along the shorelines will naturally colonize with woody vegetation. Berms were not included in the design for these islands and formed accidentally in only a few locations during construction. These berms quickly vegetated, and led to the inclusion of low level berms on future projects. 6.A.7 The top elevation of rock structures will decrease with time, either due to bottom displacement or ice action. The as-built elevation of the rock mound constructed along Swan Island was approximately 2 ft over the avg water surface elevation. This had been reduced to 1 foot or less within about 5 yrs. This was not a problem since rock mound elevations only need to be near the avg water surface elevation to function as wave breaks. From a lessons learned standpoint, it would have been nice to monitor this rock mound to determine its long-term effectiveness, however, the mound was raised when another rock job was being done in this area. 6.A.8 Vegetative stabilization is not adequate if the shoreline is exposed to sustained wave action throughout the yr. Attempts to establish vegetation on the shorelines of Swan and Mallard Island without the benefit of rock groins were of limited success.
Lake Onalaska (1989)	6.B.1 Portions of the 1V:3H riprap slopes at these islands were severely damaged when ice action displaced the rock slopes, mainly on the island tips. Using a flatter slope may have caused ice to deflect up and break rather than displacing riprap. In addition, the greater quantity of rock that usually results with flatter slopes, allows for self-healing of riprap if displacement of rock does occur. Research by the U.S. Army Corps of Engineers Cold Regions Lab indicate that rock size must be 2.5 times the typical ice thickness to minimize the chance of displacement. Since ice on Lake Onalaska reaches a thickness of 30 inches, the stone size would be exceptionally large and require special handling techniques. 6.B.2 Islands in deep water have a high rate of erosion. The deep water these islands were placed in (depths greater than 3 ft) resulted in excessive shoreline erosion due to the amount of sand that was transported offshore during the beach building process. 6.B.3 Vegetative stabilization is not adequate if the shoreline is exposed to sustained wave and ice action. The berms on these islands continued to erode for several yrs even though grassy vegetation had established itself on the berm.
Pool 8, Phase I, Stage I Horseshoe I (1989)	6.C.1 Delaying the application of bank stabilization by one yr or more may allow refinement of the overall stabilization plan, resulting in more vegetative stabilization and decreased use of rock. Less than 10%of this shoreline was stabilized with riprap even though over 50%of the shoreline is adjacent channels. Initially it was thought that riprap would be needed along the channels, however the construction sequence resulted in the sand being placed during the 1989 construction season with rock placement to be done in 1990. It was apparent by the late Spring of 1990, that only a couple of sections of the island were being exposed to erosive river currents. 6.C.2 Shallow off-shore water depths greatly reduce erosive forces. The entire backwater side of this island had off-shore water depths of less than 2 ft and extensive aquatic vegetation beds which minimized erosive forces. The woody vegetation that colonized the berm on this island provided adequate stabilization with no rock required. 6.C.3 Active sand transport in adjacent channels may aid shoreline stability. Sand transported along the island has resulted in portions of the offshore area becoming shallower since the island was constructed. 6.C.4 Placement of islands a distance back from the main channel allowed for shallow water depths to dampen towboat and recreation boat waves before reaching the berm of the island, therefore reducing the need for additional bank stabilization.

Table 9-16. Lessons Learned, Design Category 6 – Shoreline Stabilization

Project (Year Constructed)	Lesson Learned
Pool 8, Phase I, Stage II Boomerang Island (1992)	6.D.1 Constructing low berms results in rapid colonization by woody vegetation, increasing island stability during floods. Over three miles of shoreline were stabilized using berms, groins, and vegetation. Within a few yrs willow growth on the berm spreads from the water line to almost the top of the island, providing a 20 to 30 foot swath of willows. While very stable, the vegetation growth eliminates the beach zone as a habitat feature. 6.D.2 Groins are an effective low cost means of stabilizing shorelines if wind driven wave action is the primary erosive force. They were not used as a means of shoreline protection until this island was constructed. Groins were such a successful method of protecting shorelines that they have become the preferred method of protection in wave environments. 6.D.3 Shallow off-shore water depths greatly reduce erosive forces, even for wind fetches exceeding 2 miles. Vegetative stabilization is very effective in these situations. Over 60%of this island was stabilized simply by establishing vegetation on the berm (photograph D.6, Appendix A). The backwater side of this island had off-shore water depths less than 2 ft and extensive aquatic vegetation beds which minimized erosive forces. The main channel side of this island also had shallow off-shore water depths but also benefited by having active sand transport near its shoreline. The sand has resulted in portions of this shoreline becoming even shallower, providing even more reduction in erosive forces. 6.D.4 Abrupt transitions between rock structures and the earth island may cause erosion due to eddies. Strong river currents near the large bend in this island caused erosion just upstream and downstream of the riprap protection that had been placed here. The problem was caused by eddies that formed at the abrupt transition between the reach of the island that was protected by riprap and the reach that was protected by vegetation. Remedial action was taken after the 93 flood which consisted of placing additional riprap on the upstream erosion site. This stabilized the erosion site, but created another abrupt transition, eddy, and erosion at the end of the new riprap. Eventually this problem was fixed by placing small groins and an off-shore rock mound in the new erosion zone. The groins gradually diminished in size in an upstream direction, eliminating the abrupt transition. 6.D.5 Littoral drift will occur on shorelines exposed to wave action. Groins successfully eliminated littoral drift. 6.D.6 Unprotected shorelines exposed to more than 1 mile of wind fetch will erode. This occurred on the long north-south leg of this island. The water was slightly deeper here and there was not as much vegetative stabilization as the east-west leg. The orientation of the north-south leg to southeasterly winds may have contributed to excessive littoral drift. 6.D.7 Rock gradation is adequate to withstand wind driven wave action above the design wave. During the 1993 flood, when water surface elevations were near the top of the island, a storm event with straight-line winds exceeding 60mph occurred. Wave action generated by this event displaced some of the smaller stones in the riprap layer; however the riprap layer remained intact. 6.D.8 Placement of islands a distance back from the main channel allowed for shallow water depths to dampen towboat and recreation boat waves before reaching the berm of the island, therefore reducing the need for additional bank stabilization.
Pool 9 Islands (1994)	6.E.1 Some sections of this all rock island have settled.
Pool 8, Phase II, Stoddard Bay Islands (1999)	6.H.1 Wind fetches of less than one mile can cause erosion. The berm on the north side of island D2 eroded more than expected during the beach building process. The maximum wind fetch impacting this shoreline was about 4,000 ft. 6.H.2 Constructing low berms results in rapid colonization by woody vegetation, increasing island stability during floods. Almost 4 miles of shoreline were stabilized using berms, groins, and vegetation. Within a few yrs willow growth on the berm spreads from the water line to almost the top of the island, providing a 20 to 30 foot swath of willows. While very stable, the vegetation growth eliminates the beach zone as a habitat feature. 6.H.3 A 300 ft reach of island that was constructed near slightly deeper (greater than 4 ft) water had to be stabilized with off-shore rock mound due to excessive erosion of the berm.
Swan Lake, Illinois R. (1996)	6.J.1 Unprotected shorelines will have a high rate of shoreline erosion if they are exposed to erosive forces. Because of limited project funding, the shorelines of the Swan Lake islands were left unprotected. Some of these islands have lost more than 50% of their mass due to erosion.
Peoria Lake, Illinois R. (1996)	6.L.1 Borrow channel overburden material that was placed near the island has functioned as a wave break, and has reduced wave action on the island shoreline. This material has remained in place and continues to protect the island.
Pool 11 Island (2004)	6.N.1 Erosion protection was not initially specified, due to budget constraints. However widespread erosion required the construction of an off-shore rock mound.
Pool 8, Phase III, Stage 2 (2008)	6.P.1 Unprotected sand tips that were designed to erode were included in an attempt to maintain beach habitat. These sand tips, which are eroding at different rates depending on exposure to wave action, have provided what appears to be unique habitat. Continued monitoring will be done to determine longevity and habitat value. 6.P.2 Shorelines with small wind fetches were stabilized with vegetation without the need for rock structures such as groins or vanes. In some cases, mudflats or sand flats were constructed adjacent these shorelines. 6.P.3 The 40 foot berm width used on this project (previous projects called for a 30' width) has minimize concerns about berm erosion.
Pool 8, Phase III, Stage 3 (2010 & 2011)	6.Q.1 Unprotected sand tips that were designed to erode were included in an attempt to maintain beach habitat. These sand tips, which are eroding at different rates depending on exposure to wave action, have provided what appears to be unique habitat. Continued monitoring will be done to determine longevity and habitat value. 6.Q.2 Shorelines with small wind fetches were stabilized with vegetation w/out the need for rock structures such as groins or vanes. In some cases, mudflats or sand flats were constructed adjacent these shorelines. 6.Q.3 The 40 foot berm width used on this project (previous projects called for a 30' width) has minimized concerns about berm erosion.

Table 9-17. Lessons Learned, Constructability

Project (Year Constructed)	Lesson Learned
Weaver Bottoms, Pool 5 (1986)	7.A.1 Displacement of existing substrate can occur, but usually doesn't have a significant effect on construction. This happened on the south side of Swan Island, and resulted in a berm being formed, which led to the inclusion of the berm design in future projects. 7.A.2 Fine sediments can be hydraulically dredged into a containment area where they can be dried out and then mixed with sand and shaped by construction equipment. The fine sediments for Mallard and Swan Island were pumped into containment cells on the islands and allowed to dry over the winter. The contractor was able to spread the fine sediment early the next construction season.
Lake Onalaska (1989)	7.B.1 Contractors tend to meet or exceed design elevations. Based on post-project cross sections, the upper limit of the top elevation range was met or exceeded in all areas and the berm elevation was exceeded by at least 0.5 ft. This could affect the growth of terrestrial vegetation on the islands, with higher islands favoring grasses. We probably would have been better off increasing the length of the island, once the material overrun was identified.
Pool 8, Phase I, Stage I Horseshoe I (1989)	7.C.1 The dredge plume from larger hydraulic dredges, like the Dredge Thompson, with its 20-inch pipeline, results in sand being deposited over a footprint at least a 100' wide. Berming may minimize the spread of the dredge plume, however a 100' width, seems to be a reasonable footprint for larger hydraulic dredges. Horseshoe Island ended up wider than designed and in one section an effort was made to recover some of the sand and reestablish more aquatic area. 7.C.2 Fine sediments can be dried out by mechanically dredging them into a placement site where they are allowed to dry out over the winter. The fine sediments on Horseshoe Island were excavated from a wetland and allowed to dry for a yr before they were placed on the island. 7.C.3 Heavy construction equipment can operate in fine sediments as thick as 2 ft without major problems. The fine sediments on Horseshoe Island were up to 2 ft thick in places during the placement of the topsoil. This caused a few operational problems, but nothing serious. 7.C.4 Contractors tend to meet or exceed design elevations. Based on post-project cross sections, the upper limit of the top elevation range was met or exceeded in almost all cases. 7.C.5 Soil compaction of the fine material may have impacted vegetation growth.
Pool 8, Phase I, Stage II Boomerang Island (1992)	7.D.1 The services of a trained plant specialist (Botanist, Forester, etc.) should be retained during final inspection to assess the success of plantings. During the inspection of this project, there was some disagreement regarding the success of the plantings on this project. This argument was settled when a person knowledgeable was able to identify the native grasses and separate them from the weeds. 7.D.2 Fine sediments must be dried out before they can be mixed with sand and shaped by construction equipment. The fine sediments on Boomerang Island were mechanically dredged and allowed to dry out over the winter. The contractor was able to spread the fine sediment early the next construction season. 7.D.3 Heavy construction equipment was able to operate in fine sediments on Boomerang Island, which were as thick as 4 ft, without major problems. 7.D.4 Islands can be constructed using fine sediments (or a mix of fines and sand). The design of Boomerang Island included a 500-ft section that included a large amt of fines. A sand base had been placed along this reach the yr before, creating a construction base from which heavy equipment could operate. Sediments excavated from the Wildcat Creek area were transported to the site by barge and placed over the sand base and in the aquatic area behind the sand base. Side casting of fines sediments from the area adjacent the island was not used by the contractor even though this was identified as an option in the plans.
Pool 8, Phase II, Stoddard Bay Islands (1999)	7.H.1 Excess dredge material is likely to either increase the elevation of an island or the footprint. Develop contingency plans for excess material. The length of Island D1 (East Leg Slingshot Island) was lengthened by 50' because excess dredge material had been placed here. 7.H.2 Heavy construction equipment can operate in fine sediments as thick as 3 ft without major problems. The fine sediments on the phase II islands were up to 3 ft thick in places during the placement of the topsoil. This caused a few operational problems, but nothing serious. 7.H.3 Fine sediments must be dried out before they can be mixed with sand and shaped by construction equipment. The fine sediments on the Pool 8 Phase II Islands were pumped into a containment cell on the islands and allowed to dry over the winter. The contractor was able to spread the fine sediment early the next construction season. 7.H.4 The sand base, which consists of over 95% sand, and was several ft thick supported heavy equipment without any problems. 7.H.5 Hydraulic placement of fines on the islands caused segregation and less uniform soil gradations. The only locations this was seen as a problem was were the final gradation of material was approaching the upper limit of sand content, which influenced the establishment of terrestrial vegetation. 7.H.6 Contractor used sand from the island to form temporary cells for containment/dewatering of hydraulically dredged fine materials that were later incorporated with the fine material to be used as random and select fine material; this may be the most economical method of placing fines, provided the island size allows for adequate settling time of sediments.

Table 9-17. Lessons Learned, Constructability

Project (Year Constructed)	**Lesson Learned**
Polander Lake (2000)	7.I.1 Corps quality assurance personnel and design team members need to verify island position prior to construction. A survey error during the initial construction phase of this project resulted in dredge material being placed outside of the construction limits of this project. 7.I.2 A dewatering system for hydraulically dredged fine sediments was used at Polander Lake with partial success. Equipment problems forced the contractor to place about half of the fine sediments using mechanical dredging.
Swan Lake, Illinois R. (1996)	7.J.1 Use of a large (8 cubic yard) clamshell bucket improved the constructability of these islands. The larger bucket allowed the contractor to excavate larger masses of sediment preserving the cohesive strength of the sediments.
Peoria Lake, Illinois R. (1996)	7.L.1 Use of a large (7 cubic yard) clamshell bucket and constructing the island in 3 lifts improved the constructability of these islands. The larger bucket allowed the contractor to excavate larger masses of sediment preserving the cohesive strength of the sediments. Approximately 550,000 cubic yards of material was excavated for this project at a cost of $2/CY.
Bertom McCartney (1992)	7.M.1 The embankments forming the confined disposal facility (CDF) consist of fine material within the embankment, with sand hydraulically dredged over the fine material to achieve final grade. 7.M.2 The contractor divided the CDF into two cells, providing increased retention time for improved settling characteristics.
Pool 11 Islands (2005)	7.N.1 The contractor had difficulty constructing the island to the 1V:5H slope that was specified, because of the weak material that was obtained from the borrow site. 7.N.2 The fish channel is not wide enough to accommodate the crane barge forcing the contractor to over-excavate material that is not measured for payment. 7.N.3 Sections of the island were constructed from material within the containment cells prior to hydraulic dredging of backwaters. This increased the capacity of the cells.
Pool 8, Phase III, Stage 2 (2008)	7.O.1 Allowing the contractor the option to construct access pads reduced the amount of access dredging needed. Access pads are essentially a road that extends from the island towards deep water and provides an alternative way for contractors to access islands. They can either be removed after construction or left in place depending on stakeholders and government desires.
Pool 8, Phase III, Stage 3A (2010)	7.Q.1 A long reach backhoe was effective for placement of rock from shore. The reaches required were 35’ for groins and 55’ for vanes. 7.Q.2 It would be helpful if some borings were obtained after project features were designed, to make sure the borrow source has material meeting specifications. The Middle Slough granular fill borrow source had too much unsuitable over-burden for it to be usable. 7.Q.3 Bathymetry data used for planning and design was inaccurate in some places (e.g. the Island C4 mudflat), leading to changes in quantities and equipment access. 7.Q.4 A temporary haul road was used to gain construction access into an area where limited access dredging is allowed.
Pool 8, Phase III, Stage 3B (2011)	7.Q.5 Assure that there are adequate sources of fill material readily available. The Middle Slough granular borrow site ended up being unusable. 7.Q.6 A new and improved specification for as-builts is needed. 7.Q.7 Allowing the contractor the option to construct access pads reduced the amount of access dredging needed. Access pads are essentially a road that extends from the island towards deep water and provides an alternative way for contractors to access islands. They can either be removed after construction or left in place depending on stakeholders and government desires.

C SPECIAL FEATURES INCORPORATED INTO ISLAND PROJECTS

1. Seed Islands. Seed islands are rock or log structures placed in river perpendicular to currents in areas where the transport of coarse sediment (sand size) is occurring. The seed island creates upstream and downstream low velocity zones where deposition occurs and adjacent higher velocity zones where scour occurs. The desired result is the formation of an island, due to sediment accumulation in the deposition zone; and the creation of a channel, due to sediment erosion, in the scour zone. The creation of islands and channels improves floodplain structural diversity, leading to improved habitat diversity. They have been constructed with solid rock and with rock/log combinations. In some cases, sand is placed on the upstream or downstream side of seed islands during construction (photograph 9-9). These nourished seed islands are used in areas where existing conditions sand transport is low. Surveys (UMESC) and observation (USFWS) indicate that the seed islands create depositional areas and improve the use of these areas by birds.

Photograph 9-9. Seed Island With Sand Accumulated on Its Upstream Side

2. Nourished Seed Islands. Nourished seed islands are used in river reaches if coarse sized sediment transport is low (a common condition in impounded areas and backwaters) or if there is a reason to accelerate the accumulation of sand (photograph 9-10). After the seed island is constructed, sand is placed on its upstream or downstream side, and then river currents are allowed to erode and reshape the sand.

Photograph 9-10. Nourished Seed Island With Sand Placed on Its Downstream Side

3. Rock Sills. Rock sills are low rock structures that are overtopped more frequently than islands. They should be used if there is a need to increase flow into an area during floods, or if there is a desire to maintain flood flow into a secondary channel in areas where islands cut across a channel. The rock sills constructed as part of the Pool 8, Phase II (Stoddard Bay) project were very expensive. (photograph 9-11.) They were constructed with a top width of 4 meters (13 feet) so that if scour did occur at the toe of the sills, there would be enough rock to allow for self-healing. A geotechnical membrane placed in the upstream sill to reduce seepage increased the cost by nearly a factor of two. The inclusion of this geotechnical membrane was effective at virtually eliminating seepage through the structure allowing target discharges to be met the first year of the project without any modification to the project. Pool 8 Islands, Phase III, incorporated 2 rock sills and a rock/log sill. The rock sill on Phase III, Island C8, utilized chinking stone to address seepage as a cost savings measure. Monitoring the winter following construction indicated seepage was occurring through the structure. While the discharge was not measured, it was sufficient to be detected throughout the interior of the island, causing water temperatures and water velocities in the upper half to 2/3 of the water column to not meet design criteria. Seepage through rock structures has been observed at other projects also.

Photograph 9-11. Layout of the Pool 8 Phase II (Stoddard Bay) Project

Rock Sill A at the upper end of Stoddard Bay overtopped during the flood on March 29, 2010. Willow growth on the rock sill initially caught debris and impeded flow (photograph: WDNR).

4. Sand Tips. In the lower reaches of navigation pools, the annual water level variation is relatively small resulting in terrestrial vegetation extending down to the water edge and the elimination of the beach zone. In an attempt to provide more of this beach habitat, the tips of several islands that were part of the Pool 8, Phase III project were constructed of unprotected sand and allowed to reshape due to wave action and river currents. However, to limit reshaping to an acceptable extent, a layer of riprap was buried within the island a distance of 50 feet from the tip of the island. Initial observations indicate that the sand tips do provide unique shoreline habitat and are worth incorporating on future projects. Photograph 9-12 was taken on May 14, 2012, less than a year after the island was constructed. Due to wave action, a significant sand flat has since formed.

Photograph 9-12. Sand Tip on Island C7, Pool 8, Phase III

5. Sand Flats. The average elevation of the sand flats constructed on some of the Pool 8, Phase III islands was 630.4 to 630.5 (photograph 9-13). The average water surface elevations during the summer growing season (June, July, August) and fall migration (October and November) are 630.7 and 630.6 respectively. So the sand flats will be overtopped by 0.1 to 0.2 feet of water during a typical fall. A tolerance of plus or minus 0.4 feet was used for construction of sand flats so that micro-topography would be created. The specifications for this project clearly state that this is only a tolerance and that continuously over- or under-building for large reaches of mudflats is unacceptable. The width of the sand flats was 45 feet. Initial observations indicate that sand flats provide unique shoreline habitat and are worth incorporating in future projects. It is very important that the contractor understands the desired product, which in this case is sandy substrate just beneath the water surface. In the Pool 8 Phase III project, there was a tendency to construct the sand flats too high.

Photograph 9-13. Sand Flat Constructed on Island C3, Pool 8, Phase III (photograph date: June 28, 2011)

6. Emergent Wetlands (Mudflats). The typical elevation of the emergent wetlands (also called mud flats) constructed on some of the Pool 8, Phase III islands was 630.4 (photograph 9-14). The average water surface elevations during the summer growing season (June, July, August) and fall migration (October, November) are 630.7 and 630.6 respectively. So the mudflats will be overtopped by 0.2 feet of water during a typical fall. A tolerance of plus or minus 1 feet was used for construction of mud flats so that microtopography was created. The specifications for this project clearly state that this is only a tolerance and that continuously over- or under-building for large reaches of mud flats is unacceptable. The Island N7 mudflat is considered the best by USFWS staff because the dredge pipe was moved frequently during construction to prevent sediment build-up.

For the Capoli Slough HREP emergent wetlands, the mean elevation was 619.5 but the elevation could vary from 618.5 to 620.5. Again the idea was that this variation would result in micro-topography. The contractor was given guidance that generally the emergent wetland should slope away from the island. The height and width of the containment dike was left up to the contractor.

Initial observations indicate that mud flats provide unique habitat and are worth incorporating in future projects. It is very important that the contractor understands the desired product, which in this case is substrate from fine sediments just beneath the water surface. During construction, additional communication with the contractor resulted in mudflat elevations generally being constructed on the low side of the tolerance, to improve habitat conditions. Breaching the containment berm is important.

Photograph 9-14. Pool 8, Phase III, Island C4 Mudflat During Construction

7. Loafing Structures and Large Woody Debris. Loafing structures (or large woody debris) have been incorporated into several of the more recent island projects (photograph 9-15). Sometimes trees are anchored into rock structures such as groins and vanes and at other times they are simply placed along an island shoreline, knowing that they will be mobilized during future flood events. Benefits of this include loafing habitat for waterfowl, turtles, and other fauna, cover for fish, improved shoreline aesthetics, and developing an alternative to rock. Good communication with the contractor is important, so that he knows what the desired finished product is. Initial observations indicate that these structures are used and should be used on future projects on a site by site basis. In project areas, where large woody debris is abundant and is transported into the area by annual floods, there may not be a need to actually include it into the project.

Photograph 9-15. Loafing Structure Being Installed by the Contractor

8. Rock/Log Islands. Rock/Log islands have been incorporated into several of the more recent island projects (photograph 9-16). These consist of a series of logs anchored in place using rock (see photo). Benefits of this include loafing habitat for waterfowl, turtles, and other fauna, cover for fish, improved shoreline aesthetics, and developing an alternative to rock. Good communication with the contractor is important, so that he knows what the desired finished product is. Initial observations indicate that these structures are interesting and should be used on future projects on a site by site basis.

Photograph 9-16. Pool 8, Phase III, Rock/Log Island

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UPPER MISSISSIPPI RIVER RESTORATION
ENVIRONMENTAL MANAGEMENT PROGRAM
ENVIRONMENTAL DESIGN HANDBOOK

APPENDIX 9-A

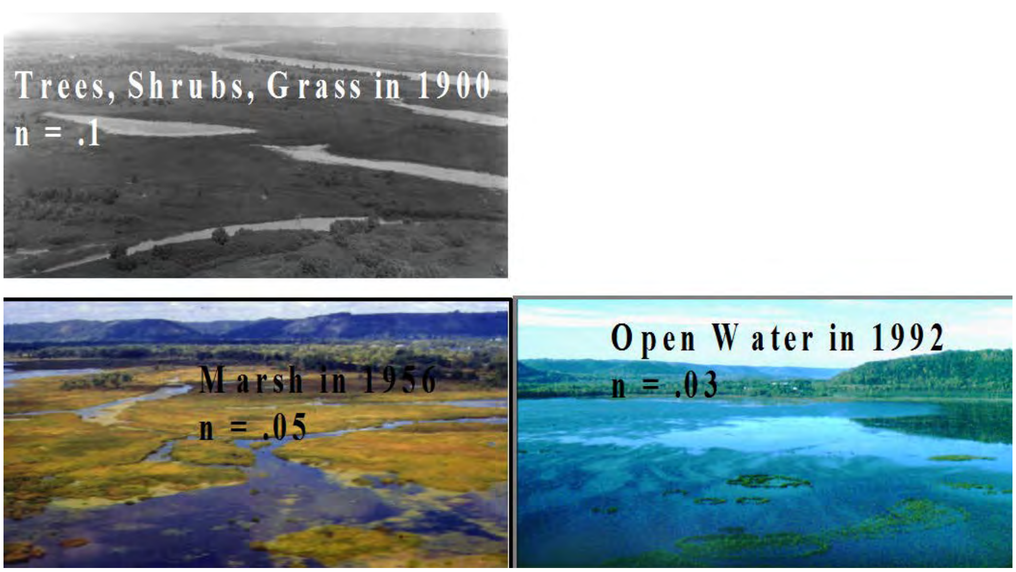
PHYSICAL RIVER ATTRIBUTES:
EFFECTS OF LOCK AND DAMS AND ISLANDS ON
HYDRAULICS, SEDIMENT TRANSPORT, AND GEOMORPHOLOGY

APPENDIX 9-A

PHYSICAL RIVER ATTRIBUTES: EFFECTS OF LOCK AND DAMS AND ISLANDS ON HYDRAULICS, SEDIMENT TRANSPORT, AND GEOMORPHOLOGY

The Upper Mississippi River (UMR) is island braided with many anastamosing side channels, sloughs, backwaters, and islands (Collins & Knox, 2003). Natural levees separate the channels from the backwaters and floodplain. In its natural state, the flow of water and sediment was confined to channels during low flow conditions. For larger floods, the natural levees were submerged resulting in water and sediment conveyance in the floodplain, however channel conveyance continued to be high since floodplain vegetation increased resistance and reduced discharge in the floodplain. The River today is a reflection of many changes that have altered the natural condition of the river (Chen & Simons, 1979; Collins & Knox, 2003). These include early attempts to create a navigation channel through the construction of river training structures, the conversion of the watershed to agricultural land-use, the urbanization of some reaches of the river, and the introduction of exotic species. However, the construction of the Locks and Dams in the 1930s is the most significant event affecting the condition of the river and most restoration efforts attempt to alter the impacts of the locks and dams.

Construction of the locks and dams submerged the natural levees and floodplain creating navigation pools upstream of the dams and leaving only the higher parts of the natural levees as islands. Submergence altered habitat in the floodplain producing a robust response of aquatic plants and animals in the shallow marshes that were created. However, because a minimum pool level is maintained for navigation, the low water portion of the annual hydrologic cycle was eliminated ($\boldsymbol{\Delta z_w}$ decreased). This degraded habitat for many plants and animals adapted to a larger range of water level fluctuations. The shift in vegetation communities (photograph 9-A-1) decreased floodplain resistance causing increased floodplain conveyance (i.e. floodplain connectivity) with time ($\boldsymbol{Q_f/Q_t}$ increased, $\boldsymbol{Qc/Q_t}$ decreased).



Photograph 9-A-1. Weaver Bottoms, Pool 5 - Changes in Floodplain Vegetation and Roughness.

Table 9-A-1 shows the effect of Lock and Dams and island construction on parameters describing hydrodynamics, sediment transport, and geomorphology in the lower portions reaches of navigation Pools 1 through 13 of the UMRS.

Table 9-A-1. The Effects of Submergence on Parameters Describing Hydrodynamic, Sediment Transport, and Geomorphic Regimes in the UMRS Lower Navigation Pools [1]

Parameter	Definition	Lock and Dam Effects in Lower Reaches of Pools	Island Effects
Q_c	Channel discharge including secondary channels	-	+
Q_f	Floodplain discharge	+	-
Q_t	Total river discharge		
Q_c/Q_t	Ratio of channel discharge to total discharge	-	+
Q_f/Q_t	Ratio of floodplain discharge to total discharge	+	-
v_c	Channel velocity	-	+
v_f	Floodplain velocity	+	-
W_c	Channel width including secondary channels	+	-
z_c	Channel elevation	+	-
z_f	Floodplain elevation	+, -	+, -
Δz_w	Difference in elevation between the 2--year flood and low flow conditions	-	
F	Wind fetch in floodplain	+	-
Q_s	Sediment load	-	+
SS	Suspended sediment concentration	+	-
D_c	Sediment deposition in channels	+, -	+,-
D_f	Sediment deposition in floodplains	+,-	+,-
E_c	Channel bed erosion	-	+
E_b	Bankline erosion	+	-
E_f	Floodplain erosion	+	-
d_{50}	Sediment particle size in channels	-	+

[1] " +" - magnitude of parameter increased; "-" - magnitude of parameter decreased

For river flows near and well above bankfull, the majority of the conveyance is now in the floodplain in the lower reaches of the navigation pools. This increased the delivery of sediment to the floodplain (D_f increased). Chen and Simons, 1979, found that the water surface for a given flood discharge in the upper and middle reaches of the navigation pools was decreased after the locks and dams were constructed (Δz_w decreased). They attributed this to the destruction of overbank vegetation, which increases the riverbed area (the flow carrying portion of the river). A comparison of water surface profiles for pre- and post-lock and dam conditions indicates that the decrease in water surface elevation was as much as 1-foot in the upper portions of the pool. Combined with the increase in water surface in the lower reaches of the pools, caused by the dams, the hydraulic slope in the pools for flood conditions as been decreased as much as 20-percent. Channel velocities (v_c) decreased and the lower reach of the navigation pools became more depositional (Qs decreased). Sediment deposition in the main channel (D_c) was increased adjacent secondary channels where flow enters the floodplain, requiring periodic dredging to maintain the 9-foot navigation channel. The combination of dredging and sediment flow to the floodplain through the secondary channels limits the supply of sand-size sediment to the lower portions of the navigation pools, which is a potential factor in increasing shoreline erosion (E_b increased). Superimposed on this lower velocity depositional system is a high velocity reach at each lock and dam, which presents a potential barrier to migrating fish. Although a significant quantity of backwater habitat was initially created by submergence, island erosion and the continued increase in floodplain conveyance have increased velocities (v_f) in many of these areas making them less suitable for plants and animals. The width of the main channel (W_c) increased in the lower reaches of the pools due to Lock and Dam construction (Chen & Simons 1979, WEST Consultants 2000, Collins & Knox 2003).

Wind driven wave action has become a more significant factor in the floodplain affecting both the transport of sediment and morphological changes in the floodplain. Many of the islands and shallow areas in the lower pools eroded (E_f, E_b increased) due to wave action (WEST Consultants, 2000) As shown in photograph 9-A-2, by 1995, wind-driven wave action eroded a group of barrier islands that had been over 1 mile to one single remnant by 1995). Sediment transport in the floodplain now is affected by daily wind conditions as much as seasonal variations due to annual cycles of basin-wide runoff. This has resulted in increased suspended sediment concentrations (***SS***).

Photograph 9-A-2. Pool 8, Phase II, Stoddard Bay Erosion

While project goals and objectives usually focus directly on the improvement of habitat in the floodplain, the physical impact of island construction is to partially restore riverine hydrodynamic, sediment transport, and geomorphic conditions. As Table A-1 illustrates, islands reverse many of the effects of lock and dam construction. A new island essentially becomes the new natural levee, separating channel from floodplain, reducing channel-floodplain connectivity, and increasing channel flow while decreasing the amount of floodplain flow (Q_c/Q_t increases, Q_f/Q_t decreases). This increases the velocity in adjacent channels increasing the erosion and transport of sediment (v_c, E_c, increased). Wind fetch and wave action is reduced in the vicinity of islands, reducing the resuspension of bottom sediments, floodplain erosion, and shoreline erosion (***F***, ***SS***, E_f, E_b decreases). In some cases, islands act primarily as wave barriers and don't alter the river-wide distribution of flow. Islands reduce the supply of sediment to the floodplain potentially decreasing floodplain sediment deposition (D_f). Constructing islands (or natural levees) is a necessary step in restoring the form, function, and habitat value in the lower portions of the navigation pools.

The natural resource managers and scientists involved in the Habitat Needs Assessment [(HNA) Theiling et al. 2000] indicated that the future river should be characterized by: improved habitat quality, habitat diversity, and a closer approximation of pre-development hydrologic variability. In fact, the subject of restoring natural conditions is frequently discussed at all levels of planning and design. However, the relationships between the flow of water, the transport of sediment, and the biota in a natural system are not always well defined. Habitat goals are developed first and then the physical conditions that will most likely achieve those goals are determined. While this will continue to be the case, HREP design teams will benefit if the physical condition of the natural river is defined. The Pool 8 Islands, Phase III project was the first to incorporate processes as an objective.

In table 9-A-2, the first column lists river attributes as defined by McBain and Trush (1997). These attributes describe the fluvial geomorphic processes that sustain ecosystem integrity. They were developed for cobble and gravel-bedded rivers in the Western United States; however, they apply, with some modification, to the UMR (column 2). All of these attributes describe the relationship between the hydrologic regime and sediment transport, and the resulting geomorphic and biologic condition of a river. Restoring these attributes on a river reach will help achieve the broad goals stated in the HNA of improved habitat quality and diversity, and more natural hydrology. These attributes, along with habitat parameters, engineering considerations, and lessons learned, form the basis for design criteria and project design once goals and objectives are defined.

Table 9-A-2. Attributes of Alluvial River Ecosystems and the Condition of Those Attributes for the Lower Reaches of UMR Pools 1-10

General Attributes of Alluvial River Ecosystem (McBain & Trush)	Conditions in the Lower Reaches of Pools 1-10 on the UMR
Attribute No. 1. Spatially complex channel morphology. No single segment of the channel bed provides habitat for all species, but the sum of channel segments provides high-quality habitat for native species. A wide range of structurally complex physical environments supports diverse and productive biological communities	Submergence of the natural levees and floodplain and subsequent island erosion has decreased main channel flow and velocity creating a more depositional condition. Dredging and sediment deposition in the middle reaches of pools limits the amount of coarse sediment transported to the lower reaches. The increased fine and course sediment transport to the backwater areas occurs at most times during the year, compared to being flood event driven prior to impoundment. With the limited supply of coarse sediment, the lower reaches of pools have remained fairly deep through time. However, there has be a simplification of the bathymetry in these lower sections of the pools as wave action erodes "high" spots and sedimentation fills in the historic floodplain depressions that are now permanently inundated (see pool 13 bathymetric comparison by USGS and the pre and post bathymetric analysis for Phase II). These factors limit the formation of complex morphological features such as point bars, longitudinal bars, and riffles with coarser sediments. The minimum water surface elevation that is maintained for navigation usually submerges sand bars that form. Wing dams create flow and substrate diversity in some reaches.
Attribute No. 2. Flows and water quality are predictably variable. Inter-annual and seasonal flow regimes are broadly predictable, but specific flow magnitudes, timing, durations, and frequencies are unpredictable due to runoff patterns produced by storms and droughts. Seasonal water quality characteristics, especially water temperature, turbidity, and suspended sediment concentrations, are similar to regional unregulated rivers and fluctuate seasonally. This temporal “predictable unpredictability” is the foundation for river ecosystem integrity.	Variability occurs at frequencies associated with inter-annual, seasonal, and storm event time scales. However wind-driven wave action causes daily and diurnal changes in water quality, especially turbidity and suspended sediment concentration in the lower reaches of pools. The increased turbidity reduces light penetration decreasing the growth of aquatic plants and affects other aquatic organisms.
Attribute No. 3. Frequently mobilized channel bed surface. Channel bed framework particles of coarse alluvial surfaces are mobilized by the bankfull discharge, which on average occurs every 1-2 years.	Channel bed sediments consist of sands that are mobilized by discharges much lower than the bankfull discharge. Measurements in lower pool 8 by personnel from ERDC indicated significant bed load movement for a discharge of 50,000 cfs, which is about 60% of the bankfull discharge (Abraham et al. 2003). However, due to submergence of the floodplain and island erosion, floodplain conveyance in the lower reaches of navigation pools exceeds 50% of the total river discharge at the bankfull flow condition. Flow velocities and the potential to mobilize and transport sand-size sediments are decreased because of this. Normally this would result in rapid aggradation of the channel bed, but dredging and floodplain deposition in the middle reaches of navigation pools limits the supply of coarse sediments. Sand that enters the floodplain deposits in deltas, on natural levees, and in other features with little chance for remobilization.
Attribute No. 4. Periodic channel bed scour and fill. Alternate bars are scoured deeper than their coarse surface layers by floods exceeding 3- to 5- year annual maximum flood recurrences. This scour is typically accompanied by re-deposition, such that net change in channel bed topography following a scouring flood usually is minimal.	The UMR is a sand-bed river and so there generally is not an armor layer that is scoured. Because of submergence and island erosion, the floodplain conveyance in the lower reaches of navigation pools is high and velocities for the 3 to 5 year floods are not significantly greater than those for the bankfull discharge.

Table 9-A-2. Attributes of Alluvial River Ecosystems and the Condition of Those Attributes for the Lower Reaches of UMR Pools 1-10

General Attributes of Alluvial River Ecosystem (McBain & Trush)	Conditions in the Lower Reaches of Pools 1-10 on the UMR
Attribute No. 5. Balanced fine and coarse sediment budgets. River reaches export fine and coarse sediment at rates approximately equal to sediment inputs. The amount and mode of sediment storage within a given river reach fluctuate, but also sustain channel morphology in dynamic quasi-equilibrium when averaged over many years. A balanced coarse sediment budget implies bedload continuity; most particle sizes of the channel bed must be transported through the river reach.	• A bed material (i.e. coarse material) sediment budget developed for the St. Paul District reach of the UMR (Hendrickson, 2003) indicates a decrease in the sediment load from the upper to the lower reach of the navigation pools. The only exception to this is where tributaries entered and caused a spike in the sediment load. This decrease is due to hydrodynamic changes and dredging. Main Channel conveyance changes from 80% of the total river discharge in the upper reaches of the navigation pools to less than 50% of the total river discharge in the lower reaches at the bankfull flow condition. Flow leaving the channel and entering the floodplain carries coarse sediment, which is trapped in deltas or on the natural levees. Channel velocities and the potential to mobilize and transport sand-size sediments is decreased as the amount of main channel flow decreases, leading to coarse sediment deposition in channels and the floodplain. The lack of a balanced coarse sediment budget leads to dredging in the navigation channel, which reduces the bed material load to a level that the lower reaches can transport. • Sediment budget studies in Pool 13 (Gaugush, 1997), Weaver Bottoms in Pool 5 (Nelson et al., 1998), and Peterson Lake in Pool 4 (Unpublished St. Paul District Data, 1995) indicate a balance between fine sediment input and output. However, transect measurements in Pools 4, 8, and 13 indicate a net accumulation of sediments and a gradual increase in the bed elevation of backwater areas (Rogala, 2003). Also, Collins and Knox (2003) found net accumulation of fine and coarse sediments on natural levees in pool 10. These were areas that are only inundated during floods. It is probable that the UMR traps more of the fine sediment load than it exports, however there certainly are reaches where there may be some type of quasi-equilibrium.
Attribute No. 6. Periodic channel migration. The channel migrates at variable rates and establishes meander wavelengths consistent with regional rivers having similar flow regimes, valley slopes, confinement, sediment supply, and sediment caliber.	• Most geomorphic studies of the UMR indicate a relatively stable main channel through time. Knox (2001), using radiocarbon dating of deep cores representing floodplain sites in Pools 9 & 10, found long-term stability of major island and floodplain landforms. Exceptions to this stability occurred where large tributaries enter the main channel, supplying a large amount of coarse sediment. Archaeological studies of the Mississippi floodplain in Pool 10 have found campsites and artifacts, dating back 1,300 to 2,000 years, buried on lateral accretion deposits adjacent present day channels. This evidence suggests that channel position has changed little in the last 2,000 years (Stoltman 1983, Church 1985). Additional archaeological data provides evidence that the position of some landforms within the valley have not changed in 8,000 years Development of the UMR for navigation, aimed to stabilize the main channel even more. Chen and Simons (1979), using a combination of river surveys and aerial photographs, found that the position of the river did not change appreciably in Lower Pool 4 with the construction of training structures and locks and dams. • However, a recent study indicates that in some areas secondary channels may have been much more dynamic, at least since the locks and dams were constructed. Carson (unpublished thesis 2004) found significant migration and expansion of secondary channels at his study sites in the Goose Island backwater in the middle reach of Pool 8. Secondary channels in the middle reaches typically have hydraulic slopes higher than .0001. This is because there is often a significant water surface differential between backwaters, which might have their main connection with the river miles downstream, and the adjacent main channel. Additional factors contributing to these mid-pool dynamics induced by impoundment may also include changes in vegetation coverage (from forest to grasses) that reduced floodplain roughness, alteration of the floodplain for urban development upstream of this location and island dissection. In the lower reaches of pools, the submergence of natural levees and the floodplain has decreased the hydraulic slope to .0001 or less and current velocities in secondary channels are well below the threshold for major channel migration.

Table 9-A-2. Attributes of Alluvial River Ecosystems and the Condition of Those Attributes for the Lower Reaches of UMR Pools 1-10

<table>
<tr><th>General Attributes of Alluvial River Ecosystem
(McBain & Trush)</th><th>Conditions in the Lower Reaches of Pools 1-10 on the UMR</th></tr>
<tr><td>Attribute No. 7. A functional floodplain. On average, floodplains are inundated once annually by high flows equaling or exceeding bankfull stage. Lower terraces are inundated by less frequent floods, with their expected inundation frequencies dependent on norms exhibited by similar, but unregulated river channels. These floods also deposit finer sediment onto the floodplain and low terrace.</td><td>The floodplain and natural levees in the lower reaches of navigation pools were permanently submerged by Lock & Dam construction. Subsequent island erosion (i.e. natural levee erosion) and a shift in vegetation communities, which decreased floodplain resistance, resulted in a trend of increasing floodplain conveyance and decreased channel conveyance with time. Channel-floodplain connectivity, whether measured in terms of number of connections or the amount of water conveyed in the floodplain increased. In many pools this trend continues today as islands erode and secondary channels get wider. One of the impacts of this is degraded conditions for backwater fish. Measurements at secondary channels in Pool 7 in 1980 (Pavlou et al., 1982) and in 1991 (Hendrickson et al., 1994) indicated a 10% increase in the amount of water conveyed through Lake Onalaska. For river flows below bankfull, 20-70% of the total river flow is conveyed in the floodplain in the lower reaches of pools. For flood conditions, floodplain conveyance is even higher (see table). This increases the delivery of sediment to the floodplain causing sediment deposition. In the submerged lower reaches of navigation pools, velocities often are too high to provide sheltered habitat to fish and other organisms.

% of the Total River Discharge Conveyed in the Floodplain in the Lower Reach of Navigation Pools Where Islands Have Been Constructed for Below Bankfull and Flood Conditions

<table>
<tr><th>Pool</th><th>River Mile</th><th>Below Bankfull</th><th>Flood</th></tr>
<tr><td>5</td><td>744</td><td>58</td><td>72</td></tr>
<tr><td>5A</td><td>730</td><td>27</td><td>46</td></tr>
<tr><td>7</td><td>704</td><td>62</td><td>74</td></tr>
<tr><td>8</td><td>687</td><td>73</td><td>88</td></tr>
<tr><td>9</td><td>656</td><td>52</td><td>-</td></tr>
</table>

Sediment transport in the floodplain now is affected by daily wind-driven wave action as much as seasonal variations due to annual cycles of basin-wide runoff. The bottom shear stress generated by waves exceeds the critical shear stress for sediment resuspension in shallow backwater areas. This can result in daily spikes in suspended sediment concentrations (SS) to levels that can be several times greater than background levels. Fine sediment export from backwaters occurs throughout the year due to wave action. The processes of sediment deposition in deeper permanently submerged areas of the floodplain and erosion of islands due to wave action in the pools has decreased the bathymetric complexity and habitat diversity in these areas.</td></tr>
<tr><td>Attribute No. 8. Infrequent channel resetting floods. Single large floods (e.g. exceeding 10-yr to 20-yr recurrences) cause channel avulsions, rejuvenation of mature riparian stands to early-successional stages, side channel formation and maintenance, and create off-channel wetlands (e.g., oxbows). Resetting floods are as critical for creating and maintaining channel complexity as lesser magnitude floods.</td><td>• Most geomorphic studies of the UMR indicate a relatively stable main channel through geologic time.
• In the lower reaches of pools, the submergence of natural levees and the floodplain has decreased the hydraulic slope to .0001 or less and current velocities in secondary channels are well below the threshold for major channel migration. Wind driven wave action eroded many of the natural levees (i.e. islands) decreasing channel velocity even more. Sand that does enter the floodplain, deposits and forms deltas with little chance for remobilization. In a few locations, coarse sediment transport has resulted in the formation of emerged sand deposits following recent floods. These deposits are colonized by terrestrial vegetation and become semi-permanent land features in the lower pools. While this process is encouraging, it is extremely small scale, and even if the rate of deposition increased, two questions remain. First, will on-going depositional processes occur at an adequate rate to replace desirable floodplain habitat lost over the last 70 years? Second, will the quality of the terrestrial habitat on these low elevation features, be of equal value to the higher elevation features that are eroded? The answer to both of these is probably no, and so construction of artificial islands is necessary to achieve the goals and objectives that have been set for the UMRS.
• Woody vegetation colonize sediment deposits in deltas & sand bars, representing early successional stages of forest development.</td></tr>
</table>

Table 9-A-2. Attributes of Alluvial River Ecosystems and the Condition of Those Attributes for the Lower Reaches of UMR Pools 1-10

General Attributes of Alluvial River Ecosystem (McBain & Trush)	Conditions in the Lower Reaches of Pools 1-10 on the UMR
Attribute No. 9. Self-sustaining diverse riparian plant communities. Natural woody riparian plant establishment and mortality, based on species life history strategies, culminate in early and late successional stand structures and species diversities (canopy and understory) characteristics of self-sustaining riparian communities common to regional unregulated river corridors.	Water surface elevations in the lower reaches of pools are maintained at a high and very stable elevation. There is very little difference between low flow conditions and flood conditions, and in some cases the water surface actually drops due to the operation of the Locks and Dams (see table below). Because of this, species diversity has decreased with time. Non-native Canary grass and mono-cultures of silver maple are the dominant species on many of the remaining landforms.
Attribute No. 10. Naturally fluctuating groundwater table. Inter-annual and seasonal groundwater fluctuations in floodplains, terraces, sloughs, and adjacent wetlands occur similarly to regional unregulated river corridors.	Water surface elevations in the lower reaches of pools are maintained at high and stable elevation (see table above). This has elevated the groundwater table in these reaches.

Water Surface Elevations for Low Flow and Bankfull Flow Conditions at Lock and Dams 4 through 10.

Pool	Low Flow Water Surface 75% Exceedance	Bankfull Flow 1.5 yr Flood	Difference (ft)
4	667.0	666.5	-.5
5	659.8	659.5	-.3
5A	650.8	650.8	0
6	645.4	644.5	-.9
7	639.0	639.0	0
8	630.7	630.0	-.7
9	619.5	620.0	.5
10	611.0	612.6	1.6

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UPPER MISSISSIPPI RIVER RESTORATION ENVIRONMENTAL MANAGEMENT PROGRAM ENVIRONMENTAL DESIGN HANDBOOK

APPENDIX 9-B

HABITAT PARAMETERS

APPENDIX 9-B

HABITAT PARAMETERS

Habitat projects alter the physical condition of the river to attain a biologic response that achieves a habitat goal. Project monitoring to determine if goals and objectives were met has provided some information regarding cause and effect relationships; however given the complexities of the Upper Mississippi River (UMR), much uncertainty remains. Development of a GIS database like that used for the Habitat Needs Assessment (Theiling et. al., 2000) allows delineation of land cover and the species likely to occur in an area. This same data could be used to develop biological models that predict the habitat response based on physical parameters like water depth, current velocity, substrate, and wind fetch. In the future, models such as these could be used during the planning and design of island projects to evaluate biological benefits. The natural river paradigm, which states that restoration to natural conditions provides the best habitat for the native species, should be considered also. However, this requires information regarding the condition of the natural river, which often does not exist, and ignores the fact that the altered river provides valuable habitat for many species. A theme similar to both habitat objectives for island projects and the natural river paradigm is the recognition that floodplains should convey water during floods, but for low flow conditions, water should be conveyed in channels with minimal floodplain flow.

Figure 9-B-1 illustrates how this has been accomplished in Pool 8 by constructing islands. Red indicates low velocity floodplain areas created by the islands during non-flood conditions.

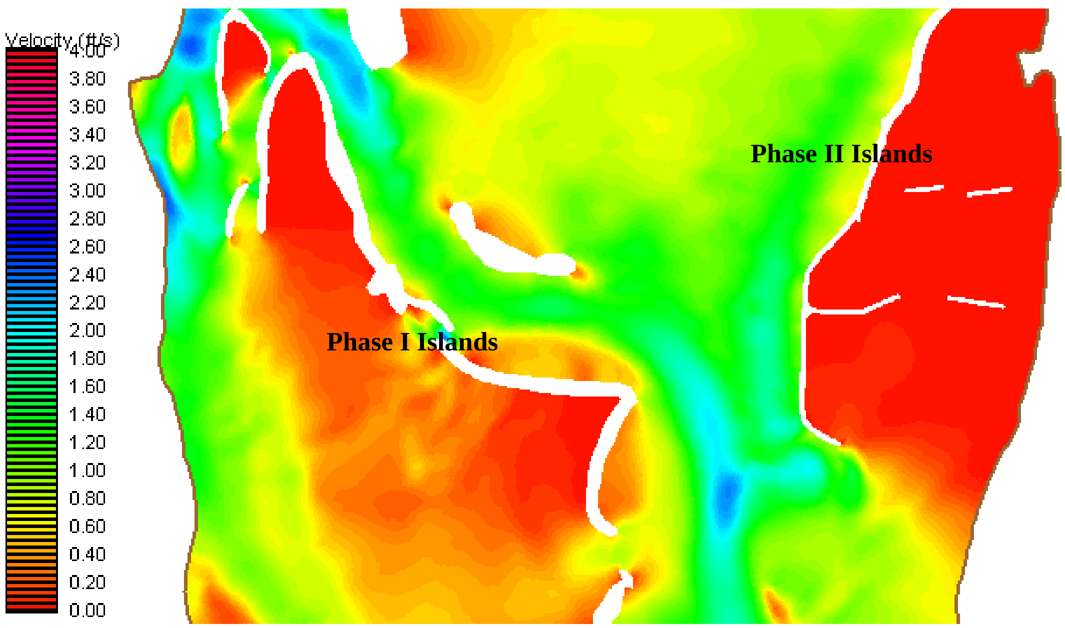

Figure 9-B-1. Current Velocity in the Pool 8, Phase I and II Areas Based on 2-Dimensional Modeling.

Regardless of the tools available to HREP design teams, the most critical factors in island design are well-articulated habitat objectives and habitat parameters that lead to the final design and ultimately to a constructed island that meets the objectives. The spatial scale these objectives and parameters cover might include the entire project area (e.g. creating specific physical and water quality conditions in the project area for backwater fish) or they may be focused on specific components of the project (e.g. the design of loafing structures associated with shoreline stabilization). The following is a list of habitat parameters that have been established for island projects to meet habitat objectives. The Fish and Wildlife Work Group (FWWG) provided most of this information. The FWWG is a group of natural resource managers and biologists established by the River Resources Forum in the St. Paul District, to study fish and wildlife issues in Pools 1 through 10.

HABITAT PARAMETER 1--FISH HABITAT

Table 9-B-1 lists the physical conditions that have been established for various species of fish. The conditions listed for Centrarchids (bluegills, bass, crappies) were established for the Pool 8, Phase II island project. This resulted in increased fish populations in Stoddard Bay (WDNR data). The objective was to create 200 acres of over-wintering habitat between the months of November and March. Island and rock sill elevations were set high enough so that overtopping during these months would occur less than once in ten years, while at the same time minimizing the number and duration of overtopping events during the remainder of the year. The depth criteria of over 4 feet provides optimum conditions, however surveys indicate that Centrarchids will use shallower depths if ice thicknesses are not too great. Groundwater inflows can have an effect on winter habitat; however, data does not exist to quantify this impact.

Table 9-B-1. Physical Conditions for Fish Habitat

Species	Velocity (fps)	Temperature (° C)	D. O. (mg/L)	Depth (feet)	Substrate
Centrarchids, Winter	< 0.01 over 80% of area	4° C, 35 % of area 2 – 4° C, 30% of area 0 – 2° C, 35 % of area	> 3	> 4 over 40% of area	
Centrarchids, Summer			> 5		
Centrarchids, Spawning	< 0.016		> 5		
Centrarchids, Nursery	< 0.016		> 5		

Other considerations include rock gradations and woody structure used on island projects. Surveys done by the St. Louis District, Corps of Engineers (Niemi and Strauser, 1991) indicate that rock gradations that include larger rocks and subsequently larger voids improved habitat for fish. Incorporating woody structure into shoreline stabilization designs could provide fish cover if the near shore depths are relatively deep.

HABITAT PARAMETER 2--FALL WATERFOWL HABITAT

Table 9-B-2 lists the physical conditions that have been established for dabbling ducks and diving ducks. These were established for the Pool 8, Phase II and Phase III island projects. Key factors to be considered when evaluating migration habitat are fall water conditions, plant species composition and

distribution, human disturbance, visual barriers, sandbars/mudflats, loafing structures and thermal protection. Generally a 50/50 mix of open water to emergent/floating leaf vegetation is considered ideal for dabbling ducks. Large bodies of water (> 200 acres) with extensive beds of submersed aquatic vegetation and limited emergent vegetation are generally more preferable for diving ducks.

Islands effectively reduce wave action up to 1 mile downwind of the island creating conditions more conducive to the establishment and maintenance of vegetation beds. The zone downwind of the island that is completely sheltered from wind is equal to 10 times the height of the island plus trees.

Table 9-B-2. Physical Conditions for Waterfowl Habitat

Habitat Type	Velocity (fps)	Wind Fetch	Water Depth (feet)	Other Desirable Features
Dabbling Duck Migration Habitat	< 0.5	< 0.5 miles	d < 0.33, 15 – 25% of area 0.33 < d < 2, 40 – 50% of area	sand bars mud flats loafing structure visual barriers thermal protection
Diving Duck Migration Habitat	< 0.5	< 1 mile	1.5 < d < 5, 40 – 70% of area	visual barriers

The following information is based on the literature and input from resource personnel on the UMR.

- Optimum water depths for dabbling ducks to feed are between 4-18 inches. In riverine conditions, deeper water that supports rooted floating aquatic plants and submerged aquatic plants may still provide food plants and invertebrates at optimal feeding depths for dabbling ducks.

- High quality habitat provides a diverse assemblage of preferred food plants as opposed to a monotypic stand of one species. The physical conditions in a riverine system create the potential for the presence of a wide variety of vegetation communities. Shallow (<2 feet), low flow areas that are protected from wind provide ideal conditions for the establishment of emergent vegetation. Deeper areas (>2 but <8 feet) that are afforded some protection from wind provide suitable conditions for a variety of rooted floating aquatic and submersed aquatic vegetation. Each of these communities may provide food/cover plants and invertebrates that are important to waterfowl during migration.

- Loafing sites/structures offer the opportunity for dabblers to rest and conserve energy. Areas with extensive loafing areas are generally higher quality than areas without. Loafing areas can be present in the form of sandflats/mudflats, low islands, tree stumps, muskrat houses or floating vegetation. Several sites scattered throughout an area are better than one large area.

- Protection from prevailing winds during severe weather allows dabblers to conserve energy. Numerous studies on large reservoirs and rivers, and observations by UMR refuge personnel, have shown that waterfowl utilize protected shoreline areas during severe weather. Cutbank shorelines, protected coves, backwater wetlands, large stands of persistent emergent vegetation or islands can all provide the needed structure to provide thermal protection. The presence of this type of habitat, a function of the downwind shadow zone of structures such as islands, on at least 5% of the area dramatically improves migration habitat value.

- Emergent vegetation can be an important component of diving duck migration habitat, but not if it is too extensive in coverage. Areas that are predominately emergent vegetation (50% or greater) are usually considered to provide minimal migration habitat for diving ducks. Emergent vegetation beds may be used by diving ducks later in the migration season when the plants have withered and the areas are more characteristic of open water.

- Invertebrate populations can be a key food source for diving ducks during migration (especially in the spring). Many species (such as mayflies, midges and snails) are associated with submersed and rooted floating leaf aquatic vegetation beds. Fingernail clams are also important; they seem to thrive best in areas that are fairly deep (3-8 feet), have flat bottoms and have current velocities between 0.1-0.3 fps.

- Susceptibility of an area to human disturbance may lower the value of an area as migration habitat. Disturbance in a migration area limit feeding opportunities and force the birds to expend energy in avoidance activities. In some cases the disturbances from bird watchers, researchers, fisherman and boaters may have as great an impact on specific birds as the more obvious disturbances such as hunting. Islands and or extensive beds of emergent aquatic vegetation can provide visual barriers between potential sources of disturbance and aquatic habitat. Large areas and multiple lines of barriers may often lessen the disturbance factor.

- The presence of extensive, protected aquatic vegetation beds is important in providing valuable migration habitat for waterfowl. While the design criteria provide conditions that are favorable for the establishment of aquatic vegetation in a mix that is desirable for the target species, it must be recognized that a variety of other conditions may affect the establishment or maintenance of aquatic vegetation including water quality, water levels during the growing season and the presence of invasive species.

HABITAT PARAMETER 3--AQUATIC VEGETATION

Earlier sections of this report have described how island erosion by waves, ice and river currents have reduced the number and acreage of islands in the lower sections of many pools in the St. Paul District. When an island is lost due to erosion, the impact is more than losing some land within the River's floodplain. A chain of events begins to occur. River currents now enter into the once protected area, increasing velocities and uprooting some of the vegetation beds. More vegetation beds are uprooted and lost because of the unchecked energy of waves rolling across miles of open water. The waves continue to build in size and eventually begin stirring up sediment from the bottom. Once the sediment is suspended in the water turbidity is increased, acting like a liquid veil, shading out light the underwater plants need to grow. Islands provide floodplain structure that can reduce the impact of wave action and current on aquatic vegetation.

Meeting the habitat objectives for many island projects includes providing suitable physical and chemical conditions for the germination, growth and maintenance of emergent, floating leafed and submersed vegetation. Aquatic vegetation provides food resources and cover for a variety of species. Aquatic vegetation also provides a wave damping affect that reduces shoreline erosion and sediment resuspension.

The Pool 8 vegetation stratified random sampling (SRS) data from the Environmental Management Program's Long Term Resource Monitoring Program (EMP-LTRMP) was merged with a velocity model developed by the COE (90,000 cfs) and the bathymetry data. Table 9-C-3 summarizes the velocity and depth ranges in aquatic areas where emergent and floating leaved vegetation was present at SRS sites from 1998 to 2004. Over 80% of the emergent vegetation was present at locations with <0.6 m of water and velocities <0.1 m/sec. Over 80% of the floating leaf vegetation was present at locations with <0.8 m of water and velocities <0.1 m/sec. The preferred limit for water velocities is most likely less than indicated by this simple analysis since a flow of 90,000 cfs represents approximately a 2 year flood event.

Table 9-C-3. EMP LTRMP Vegetation SRS Points Where Emergent and Floating Leaf Vegetation Were Present Merged With Water Depths and Velocities (from model of 90,000 cfs flow)[1]

	Floating Leaf Vegetation		**Emergent Vegetation**	
Water Depth (m)	**SRS Points Present**	**%**	**SRS Points Present**	**%**
< 0.2	374	45%	350	58%
0.2 - 0.4	135	16%	104	17%
0.4 - 0.6	115	14%	69	11%
0.6 - 0.8	94	11%	35	6%
0.8 - 1.0	71	8%	28	5%
1.0 - 1.2	28	3%	8	1%
1.2 - 1.6	16	2%	11	2%
1.6 - 2.0	4	0%	2	0%
2.0 - 2.5	1	0%		
2.5 - 3.0	1	0%		
Totals	**839**	**100%**	**607**	**100%**
Velocity (m/sec)				
0	666	77%	491	76%
0.0-0.1	75	9%	42	6%
0.1-0.2	77	9%	42	6%
0.2-0.3	24	3%	14	2%
0.3-0.4	11	1%	19	3%
0.4-0.5	8	1%	19	3%
0.5-0.6	3	0%	11	2%
0.6-0.7	2	0%	5	1%
0.7-0.8	3	0%	3	0%
0.8-0.9			1	0%
1.0-1.1			1	0%
Totals	**869**	**100%**	**648**	**100%**

[1] Total points for Water Depth do not equal the total points for Velocity since model and bathymetry were not available for all areas in which SRS data was collected.

The following criteria were developed during planning for more recent HREPs and also include additional criteria proposed by a subgroup of the FWWG for consideration in the design of future island complexes to improve environmental conditions aimed at aquatic vegetation communities. Several of the criteria are based on queries of the LTRMP databases and will require additional analysis to refine the recommendations. This additional analysis is recommended to occur in the near future.

Some of the criteria are presented as a range. Diversity for these will most likely result in colonization and maintenance of a variety of species within the specified community. However, more specific criteria can be developed for specific species by further literature review, queries of the LTRMP database or research. Establishing the objectives will require the planning team to consider the best ecological potential in the area. Ideally, a project should be designed to meet the needs of all aquatic vegetation communities to provide the most habitat benefits. Water depths within the project area will be a major factor in determining the distribution and aerial extent of aquatic vegetation communities.

Emergent Vegetation

Water Depth: <0.6 meters

Water Velocities: 0.0 m/sec preferred, <0.1 m/sec acceptable over portions of the area

Substrate: Wide range, but not highly organic/flocculent or pure sand

Wind Fetch/Island Placement: Determine based on equation provided under Engineering Consideration 4**:** Wind-driven Wave Action for the water depth <2 feet that makes up the majority of area in shadow zone of island (for example, if 75%, of the water depth in the shadow zone of the island is 1 foot, then spacing should be based on minimizing sediment resuspension in 1 foot of water).

Rooted Floating Leaf Vegetation

Water Depth: <0.8 meters

Water Velocities: 0.0 m/sec preferred, <0.1 m/sec acceptable over portions of the area

Substrate: Wide range, but not highly organic/flocculent or pure sand

Wind Fetch/Island Placement: Determine based on equation provided under Engineering Consideration 4**:** Wind-driven Wave Action for the water depth 3 feet that makes up the majority of area in shadow zone of island (for example, if the majority (i.e. 75%) of the water depth in the shadow zone of the island is 1.5 foot, then spacing should be based on minimizing sediment resuspension in 1.5 foot of water).

Submersed Vegetation

Water Depth: June-September water depth 1-4 feet range, best around 2-3 feet

Water Velocities: June-September velocity 10 cm/s or less (higher upper limit is suggested to give Vallisneria an edge to compete with coontail and elodea).

Substrate: Silt/clay is the best substrate for most species except Vallisneria americana and Heteranthera dubia which prosper on 'sand with silt' substrate best.

Wind Fetch/Island Placement: Wind fetch 1,000 m or less

Likely active responders include coontail (*Ceratophyllum demersum)*, Canadian waterweed (*Elodea canadensis*), water stargrass (*Heteranthera dubia*), Eurasian watermilfoil (*Myriophyllum spicatum*), and American wildcelery (*Vallisneria americana*).

It may be more desirable to have multiple openings of flow into the HREP area, especially near the shoreline (some flow there may help suppress lotus). Several different “types” of floodplain structures were recommended for meeting physical parameters for aquatic vegetation. Several of these structures have been incorporated as features of completed projects: Islands, sand/mud flats, seed islands and isolated wetlands in conjunction with island construction.

The following observations were provided regarding vegetation response at the Polander Lake HREP, an HREP that also included the construction of isolated wetlands (Drieslein, Robert. "Personal Correspondence." 2005; United States Fish and Wildlife Service, Winona)

> *"The best response from vegetation, particularly emergents, was in Interior island No. 1. This was not surprising since this was the one that had the fines pumped into it. Water depths within the three interior islands were in the 2 1/2 - 3 foot range, which is too deep for emergents except on the margins. On island 1 we pumped in fines and reduced water depths to about one foot, which created an environment for emergents to grow. Floating-leaved aquatics like lotus and water lilies responded positively throughout the interior complex. It appears that aquatic plant beds outside the island perimeter have increased in size, due to the shadow effect affording protection from wind and wave action. Diving duck (primarily canvasback) use in the Pool 5A closed area which includes the island complex, was greater in fall, 2004 than in any year since the islands were built."*

Water level management, both small scale and pool wide, has been used to provide environmental conditions suitable for the establishment of aquatic vegetation, especially emergent vegetation. The effects of periodic water level management are more prolonged in areas protected from river currents and wind fetch.

Other Design Considerations. Monitoring of emergent vegetation beds that grew in response to water level management in Pool 8 during 2002 and 2003 drawdowns showed herbivory by muskrats and waterfowl can have an impact on the emergent vegetation bed. Observations from these monitoring efforts indicate some consideration may need to be made to reduce suitable habitat for muskrats in some areas. Some potential design considerations to reduce the impacts of muskrat feeding on the emergents include:

- Shallow "breakwater" type islands that would provide poor quality shelter for muskrats
- Greater slopes on the island to prevent burrowing activity
- Provide greater variety of slope of the island (sacrificial berm tie in to the main island) based on water depth/fetch.

Monitoring/Research Needs. The interagency team formed to refine the island design criteria for aquatic vegetation identified several potential monitoring and research needs to better define criteria for the establishment and maintenance of aquatic vegetation. Following is a partial list of these needs, however, many other needs have been identified in other planning efforts:

- Query/analysis of existing LTRMP data to further develop and define physical factors affecting aquatic plant distribution with the Mississippi River floodplain.
- Impact of velocity on germination and growth of various types of aquatic vegetation.
- Effects of island on seed and tuber transport and settlement.

- Impacts of animal feeding activity on aquatic vegetation.
- Changes in animal use patterns after island construction.
- Complimentary benefits of island construction and water level management:
    - Affect of island and water level management on distribution of submersed vegetation.
    - Animal use patterns before and after island construction and water level management.

HABITAT PARAMETER 4--TERRESTRIAL VEGETATION ON ISLANDS

The Anfang and Wege Report (2000) provides a large amount of information on the establishment of vegetation on islands and dredge material placement sites. The following observations by Anfang and Wege are listed because of their direct implications for island projects.

The establishment of vegetation on HREP projects was successful and helped reduce site erosion, improved aesthetic appearance, and provided valuable wildlife habitat.

- Fine material increased the density of vegetation (both planted and naturally occurring).
- Six inches of fine material should be the minimum used for capping. The percent cover was highest on vegetation sites that were capped with more than 1 foot of fine material. A thicker cap of fine material with a higher percentage of fines may encourage a dense growth of woody and herbaceous cover.
- A higher percentage of seeded species were dominant on sites with more than 1 foot of fine material (68%) than on sites with less fine material (56%).
- Fine material sites with more than 35% silt/clay had a higher average percent cover than sites with lesser amounts. At least 15% fines in the topsoil is sufficient to establish vegetation, however.
- The fine material should contain sufficient coarse material to allow for aeration and water infiltration. This should be included in the specifications for the project.
- Switchgrass was recorded as the most common species on vegetation sites twice as often as any other species. At some sites the high density of switchgrass may have reduced the abundance of other vegetation by shading or other means.
- It may take several growing seasons (three to six) before vegetation reaches a desired/maximum density.
- The monitoring effort could not explain why some vegetation sites quickly convert from grasses to dense herbaceous and woody vegetation. Possible explanations include the proximity of some sites to other woody vegetation, whether or not the site was seeded to grass in the first place, the elevation of the site (higher sites favoring grasses), and the depth and consistency of fine sediments used as topsoil.
- 8-inches of fine sediment is too much for disking with standard farm equipment

Soils (Urich, 2005)

- Coarse, sandy dredged material is a poor medium for plant growth. It is important to incorporate some form of organic material with the sand to provide a suitable environment for seed germination, plant establishment and survival. To date, UMR revegetation projects have generally utilized fine sediments dredged from backwaters for topsoil. This has worked well. Sewage sludge and compost are other options being explored on a limited basis.
- Fine material placement techniques that have worked successfully include: mechanical dredging in backwaters with placement using front-end loaders; hydraulic dredging in backwaters using containment cells for placement on the site and follow-up spreading and incorporation with heavy equipment; use of an irrigation sprayer to apply fine material dredged from a backwater using a small hydraulic dredge; and use of dump trucks to deliver topsoil where the project site is accessible by land.
- Ideally, fine material and soil amendments should be incorporated into the base material. As a general rule, 6-12 inches of soil depth will support bottomland hardwood trees. Six inches of soil depth is often suitable for planting grass and forbs, with dry prairie species possibly requiring a bit less.
- Fine sediments with a high percentage of clay may be more difficult to establish trees on. This is especially true if there is significant compaction from heavy equipment during construction. One potential solution is the use of power augers during tree planting to loosen the soil in the planting hole.
- To help promote long-term survival and health of vegetation plantings, project sponsors should be encouraged to monitor soil nutrient levels at reasonable intervals after the project is completed. Color and condition of foliage plus plant size may be used as an initial indicator. If a problem is suspected, a soil test will confirm the nutrient levels and can be arranged through local extension offices. Follow-up action may include application of fertilizer.
- Soil erosion can be very effectively controlled using vegetation. However, soil-holding capabilities vary between plant type and species. It is important to consult a vegetation specialist during the island planning and design phase to help with plant selection.

Elevation

- Even within the floodplain, the flood tolerance of different plant species varies considerably. Elevation differences of six inches or less can determine whether a site will support certain types of plants. Therefore, it is very important to match plant species to island elevations. A good general reference is Whitlow and Harris, 1979.
- Post-construction flooding on low elevation islands usually results in establishment of new plant species from seed that is washed onto the site. Sometimes this new vegetation can significantly change the original composition and density of plants, and often includes undesirable species, such as vetch, purple loosestrife, reed canary grass and others. Therefore, it is recommended that simple, relatively inexpensive planting mix be used on these lower areas.
- Mast is an important diet component of many wildlife species and the most important mast-producing tree found within the bottomlands of the UMR in the St. Paul District is swamp

white oak (*Quercus bicolor*). The La Crescent Natural Resource Project Office surveyed a number of locations in 2003 and determined that the average minimum elevation above mean pool elevation where swamp white oak occurs is 2.17 feet, and for black oak (*Quercus velutina*) it is 3.01 feet. While this conclusion is based on data from only three pools, it at least establishes rough guidelines.

- Consider flood frequency and current velocity before using tree shelters on low elevation islands. Floodwaters can tip over or remove shelters, resulting in dead, deformed or damaged trees. Tree mats may not hold up on low areas either, but are more likely to stay in place than shelters. The weed control that mats provide may still be worth the risk of using them on low areas.
- An excellent set of modeling tools are available to assist in selecting sites, trees species, and tree sizes for successful reforestation. These flood potential models for the Upper Mississippi and lower Illinois Rivers are available from USGS at http://www.umesc.usgs.gov/reports_publications/psrs/psr_2001__01.html.
- Islands have the potential to support diverse stands of vegetation that can then provide benefits such as wildlife habitat, visual barriers, and protection from wind. Vegetation types include bottomland forest, grassland, and shrubby woody vegetation. Designing islands with diverse topographic relief provides managers with a greater number of vegetative options

Grass and Forbs

- Recommend using a diverse mix of native grass and forbs to ensure good overall survival. Wildflowers can enhance the appearance of the site.
- An excellent reference is Anfang and Wege (2000).
- The Spring Lake EMP project delivery team designed two grassland seed mixes in 2004 for use on islands as shown in the following two tables. For sections of islands where vegetative management will be minimal, the abbreviated prairie mix should provide a relatively quick cover of native species (table 9-C-5) . On higher sections (4 feet above average pool), the diverse prairie mix is recommended (table 9-C-6). Planners should be advised that active management is required to maintain a grassland on the river, to include mowing during establishment of the stand and periodic controlled burns later to control invasive species and woody vegetation. In addition to providing habitat benefits, native prairie grasses form deep, dense root systems that will ultimately provide more protection to the islands.
- On projects where mulch is utilized, planners should consider weed-free certified mulch. The Minnesota Department of Transportation has such a program and vendors are listed on their website. By using this mulch, the risk of infesting your island with an invasive plant species is much reduced.

Table 9-C-5. Abbreviated Prairie Mix

Common Name	Scientific Name	Seeding Rate (ounces per acre)
Virginia wild rye	*Elymus virginicus*	48
Wild Canada rye	*Elymus Canadensis*	48
Switchgrass	*Panicum virgatum*	32
Indiangrass	*Sorghastrum nutans*	16
Prairie cordgrass	*Spartina pectinata*	3
Black-eyed susan	*Rudbeckia hirta*	2

Table 9-C-6. Diverse Prairie Mix

Common Name	Scientific Name	Seeding Rate (ounces per acre)
Big bluestem	*Andropogon gerardii*	25.5
Little bluestem	*Andropogon scoparius*	25.5
Sideoats grama	*Bouteloua curtipendula*	25.5
Rough dropseed	*Sporobolus compositus*	1
Virginia wild rye	*Elymus virginicus*	25.5
Wild Canada rye	*Elymus canadensis*	25.5
Switchgrass	*Panicum virgatum*	4
Indiangrass	*Sorghastrum nutans*	25.5
Prairie cordgrass	*Spartina pectinata*	2
Black-eyed susan	*Rudbeckia hirta*	3
Evening primrose	*Oenthera biennis*	2
Purple prairie clover	*Dalea purpurea*	3
Brown-eyed susan	*Rudbeckia triloba*	2
Yellow coneflower	*Ratibida pinnata*	2
Bergamot	*Monarda fistulosa*	1
Blue vervain	*Verbena hastate*	1.5
Hoary vervain	*Verbena stricta*	1.5
Sky blue aster	*Aster oolentangiensis*	0.5
Frost aster	*Aster pilosus*	0.5
Showy sunflower	*Helianthus laetiflorus*	0.5

Trees

- It is important to quickly establish vegetation in the littoral zone of newly created islands in order to protect them from erosion. Black (*Salix nigra*) and sandbar willow (*Salix exigua*) cuttings have been successfully planted on EMP islands in the past and are planned for future projects. Cuttings are collected in the spring prior to leaf-out and are cut 20-25 inches long, as straight as possible, and range from 3/8 to ¾ of an inch in diameter at the small end. They should be planted as soon after cutting as possible or stored properly. If planting will take place within a few days, the cuttings may be kept safely by placing the butt ends in water or by heeling-in in moist soil. Cover with wet burlap sacks to prevent exposure to sun or wind. If longer storage is needed (i.e. until after the start of the normal growing season), the cuttings should be placed in cold storage with temperature between 28 and 32 degrees F. The cuttings may be bundled together, stacked, and covered with moist burlap. Moisture should be maintained by lightly sprinkling with water as needed. Planting rods made of rod iron with a handle and step, or small power augers have been used successfully to plant cuttings quickly. If soil moisture is high, the cuttings may be pushed into the ground by hand. If rods or augers are used, the cuttings should be pushed to the bottom of the hole to prevent air voids. Approximately 5 inches of cutting should remain above ground and the top of the hole should be closed with a kick of the heel. Eastern cottonwood (*Populus deltoides*) cuttings can also be planted above the littoral zone on newly created islands using similar techniques. Other species that can be established easily with cuttings are dogwoods (*Cornus sp.*) and indigobush (*Amorpha fruticosa*).

- Willow and cottonwood seedlings often regenerate naturally and fairly quickly on sites at low elevation. In some cases, it may be possible to rely on natural regeneration, in combination with a protective cover of grass, to meet vegetation establishment goals. These sites may eventually succeed into floodplain forest. However, the potential exists for invasive species such as reed canary grass (*Phalaris arundinacea*) to form dense monocultures. Actively planting islands is the preferred option in most cases.

- Consideration should be given to using large-sized (3 ft. or greater) tree seedlings for reforestation of bottomland hardwoods. Although the cost for planting materials and labor for planting are higher, survival and growth are generally better. In addition, the larger seedling stock can be planted at a wider spacing, saving on overall costs. Most private nurseries and some state nurseries can supply large seedlings. A fairly recent innovation in tree seedling production is the RPM tree, or root production method. Local tree seed can be collected in the vicinity of the project site 18 months prior to construction, then delivered to the nursery where the seed is grown into RPM seedlings. Average seedling height when ready for transplant is 4-7 feet. Survival and growth characteristics of these seedlings have been excellent, mainly because of the robust root systems that are produced in the RPM process. RPM seedlings can be available for either fall or spring planting.

Establishment

- Tree plantings have been successfully established in both the spring (mid-April to mid-June in MVP) and fall (mid-Oct to mid-Nov in MVP). Seedling availability from nurseries is usually better in the spring.

Long Term Maintenance

- Tree plantings need weed control for a minimum of three years. Tree mats can provide this and are highly recommended at the time of planting. But depending on the height growth of surrounding grasses, even trees with mats may need weed control for several growing seasons after they are established.

- Tree shelters also require regular maintenance. Floods and wind can tip the shelters over or cause them to lean. Other vegetation can grow up inside the tube and choke out the seedling. Use caution when cleaning out tree shelters during the summer and fall as they sometimes contain bee and wasp nests inside the tube.

Other Considerations

- Tree shelters come in various heights. Four to five foot tubes are good if the potential for deer damage is severe. However, shorter tubes (2-3 foot) may be adequate for protection from other animal damage. Of course, the shorter tubes are cheaper and easier to install.
- At low elevations, tree shelters can collect significant amounts of sediment during flood events, sometimes causing seedling mortality.
- Avoid using tree shelters on plantings where prescribed fire is to be used within five years of project completion.
- If possible, avoid row planting of tree seedlings to make the site look more natural and improve aesthetics.
- Quality assurance is very important during contract planting operations to ensure seedling survival and success. Among the critical items to check for is how well the planting stock was protected during storage and handled during planting. The sensitive roots of seedlings must be kept cool, moist, and out of the wind and sun from the moment they are lifted out of the nursery bed until they are covered with soil in the transplant location.
- Quality assurance is also very important in verifying the source of planting materials. The general guideline is to acquire materials where the seed source is within 200 miles of the project location. Closer is better. The seed source should also be from a parent plant that actually germinated and is growing in a floodplain environment.
- Voles and other rodents can cause severe damage and mortality to tree plantings by girdling the lower stems and/or roots. Tree shelters, tree wrap, and rodent repellants are among the options that have been used to address this problem. However, tree shelters must be properly installed so as not to leave a gap at the base of the tree for rodents to enter.

HABITAT PARAMETER 5--LOAFING HABITAT

Islands and associated shoreline stabilization structures provide loafing habitat for many species. The Fish and Wildlife Work Group (FWWG) established the following parameters for loafing habitat. The FWWG is a group of natural resource managers and biologists established by the River Resources Forum in the St. Paul District, to study fish and wildlife issues in Pools 1 through 10.

Design Criteria for Logs

Height Above Water: Main trunk of the tree should be gently sloped so that with changing water levels there are loafing areas available most of the time and turtles can climb on easily. It would be ideal if the tree had multiple branches so the bottom branches provide fish cover while the upper branches provide loafing areas - even during high water.

Mixture of elevations is best, due to the different preferences and capabilities of different species and varying water levels. Two to 12 inches or more above summer levels is recommended.

Pelicans, cormorants, eagles, etc, like open areas and 2 to 3 feet above the water seems to be better than near the surface. Most ducks seem to like structures that are a few inches above the water surface. Herons and egrets will readily perch on logs that are just under the surface to a little above the surface. Turtles, snakes, ducks and some other critters will want logs that are submerged in one area and out of the water in others. This allows them to swim up to the log and easily climb out of the water. The larger birds like pelicans, cormorants and eagles prefer to fly to a branch that is above the surface. The added height helps provide for an easier take-off.

Length: 25 foot minimum length, the longer the better **-** 60 ft. plus could be used.

Diameter: Trunk diameter of 10 inches or greater would be best. Bigger logs are easier for some wildlife to access at varying water levels and are generally available at more levels. They may persist longer as well. Bigger logs seem to hold up better and appear to attract more water birds. Smaller logs will be more prone to breaking with ice movement. Logs larger than 2' are a lot harder to work with and likely do not attract anything more than a 1' diameter log would.

Tree Species: Trees like black locust will last a lot longer while others like cottonwood might rot faster. A list of tree species in priority order based on resistance to rot, density and possibly other characteristics is discussed in engineering consideration 7 (EC 7). Preliminary list based on longevity ***BEST:*** black locust, white oak ; ***WORST:*** willow, cottonwood, box elder. Other species would fall in between

Location (sheltered areas versus windswept areas, backwaters versus channels): Areas sheltered from wind-generated waves in both backwaters and along secondary/tertiary channels would be best. Different species of turtles prefer different flow/depth conditions. When basking, most prefer calm winds, small waves and plenty of sun in a low traffic area.

Most should be located in sheltered backwaters, although if possible some should be placed in flowing channels for riverine turtles, amphibians, birds and other critters. Also, placing some in deeper areas could attract fish.

Wood ducks, teal and some other ducks like secluded quiet backwaters, while mallards seem to like a more wide open area.

Number of Logs Needed for a Structure (multiple logs versus single logs): Multiple logs with variable trunk and branch heights at any given location (as described above) would probably be best. Single trees would work too if that is all that is available or doable. Multiple logs do not need to be bundled. Logs grouped together offer more options available at one site, plus multiple logs tend to create a quiet zone around them.

The effects of ice on the log structures are unknown. Rock holds up reasonably well, but ice damage has occurred at some sites (e.g. rock on Broken Gun Island, Brice Prairie barrier island in Pool 7, Trempealeau NWR Pool 6). If the Rosebud Island logs are damaged, we may want to consider putting logs in cover or the inside of a bend where they won't be sticking out for the ice to hook them.

If anchoring loafing logs within the rock of the groins or mounds, it would be a good idea to fill the rock voids with sand within a radius of 20 feet or so from the trunk/rock interface to avoid luring small creatures to being accidentally trapped in the rock.

Loafing logs can be anchored into the shoreline of an island by notching the bank, placing the root mass and covering with rock. This technique was used successfully on Indian Slough in Pool 4 and Polander Lake in Pool 5A. Extremely large, spreading root masses might have to be partially trimmed or removed on some species before placement.

HABITAT PARAMETER 6--NESTING HABITAT

The following is a brief synopsis of parameters that have been established for nesting habitat.

Waterfowl (Devendorf, 2005)

Establishment of adequate vegetation cover on islands can provide nesting habitat for waterfowl. While isolated wooded islands can provide suitable nesting habitat, dense grassy vegetation is preferable. Large islands may be designed to provide waterfowl nesting habitat, but they may become a significant management issue if predators become established on the island. The following criteria have been identified by UMR resource managers as guidelines for islands designed as nesting habitat

- Locate island at least 1/2 mile from the nearest land
- Locate island within 1/2 mile of brood habitat (emergent aquatic vegetation)
- Size: <1 acre (< 1/2 acres is ideal)
- Vegetation cover should have an obscurity reading of at least 1.5 dm (6 inches)

Grassy and herbaceous cover, dominated by grasses is the preferred vegetation. Scattered brush, grapevines and small trees are acceptable. Woody plants need to be controlled by periodic prescribed fire, which will also rejuvenate the vigor of the nesting cover. Approximately every 5 years is a common interval. Residual (from previous growing season) cover should provide at least 70% visual blocking at a .3 foot height. 100% visual blocking (of a Robel Pole) is greatly preferred. Fertilization is not needed for establishment if 1 foot or more of fine particle soils are used to cap the island. Prairie grasses, like switchgrass, are preferred since they resist flattening by snow better than most cool season grasses. Please refer to seed mix #2 being used at Spring Lake (Pool 5) and the Pool 8, Phase III islands. The following criteria should be used for islands designed as nesting habitat

- 0.1 to 5 acres. in size, 0.5 to 2.5 acres preferred
- At or above 10 yr. flood elevation (5 yr. minimum)
- 700 feet or more from permanent shoreline
- Adjacent to brood cover, "hemi" marsh or emergents interspersed with submergents
- Free of mammalian predators - small (.5 to 1 acre) islands are best in this regard
- No trees or other perches higher than 4 feet

Turtles (Johnson, 2005)

Aquatic Plants. Islands should be designed and located as to support the development of aquatic plant beds and protect existing plant beds. Aquatic plant beds in shallow backwater areas provide cover and food resources for nesting turtles and are necessary to insure the recruitment of hatchlings into the turtle communities. Following nest emergence, hatchlings tend to move towards protected areas with aquatic vegetation. Aquatic plants also provide staging areas for nesting turtles (some species are capable of producing two or more clutches of eggs over a single nesting season). Aquatic vegetation can provide a refuge from higher flow velocities during moderately high discharge periods.

Islands should be designed to break up long, open-water wind fetches in order to reduce wind wave heights, resuspended sediments, island erosion, and protect aquatic plant beds.

Pond/Backwater Turtles Species. Nesting sites should be located near shallow waters (<6 feet depth) that are well vegetated in a mixture of submersed and emergent plants. Soft to moderately soft substrates in shallow water with little to no flow velocity is desirable for over-wintering turtles. Coarse woody debris and rock groupings can be used to create flow velocity shelters near the bottom of the backwater within these over-wintering areas.

River Turtle Species. Nesting sites should be located near low to moderate flow velocity areas during the open water season with water depths ranging from shallow to very deep (20 feet +). Well to moderately vegetated areas should be in close proximity to the deeper water. Over-wintering refuges are found in areas with low velocities, water depths ranging from 8 to 30 feet. Again, large woody debris and rock can be used to create zones of reduced flow velocities near the bottom to improve over-wintering conditions.

Island Spacing. Islands spaced 500 feet apart or greater may reduce predation rates. Sparsely vegetated islands located some distance away from large, moderately vegetated islands may provide a refuge from high predation rates. It is recognized that islands spaced too far apart may reduce their effectiveness in reducing wind generated waves and their associated problems.

Deadwood/Loafing Structures. Map turtle densities have been correlated to nearby deadwood densities. The incorporation of deadwood into island design would provide refuge, basking, over-wintering and foraging areas for all size classes of riverine turtles. Deadwood placement should not be uniform but rather include the clustering of varying size branches and trunks entering the water at irregular intervals, various angles and elevations. Large woody debris, coarse woody debris and deadwood are terms used to describe tree snags and can be used interchangeably. Additional guidance on loafing structures (tree snags placed near shore and for the most part above water) has already been provided by the FWWG.

Rock Shoreline Protection. Rock shoreline protection and offshore mounds should be avoided in areas designed to attract nesting turtles to avoid accidental trapping of hatchlings. Rock can be a trapping hazard for some adult species of turtles as well. Rock groins and vanes may be better choices when rock stabilization is required, especially if the rock is choked with gravel or sand to eliminate the trapping hazard.

Nesting Areas. A mixture of nesting area sizes is ideal. Large nesting areas may promote lower predation rates because of reduced nest detection efficiencies. Small nesting areas may go undetected and therefore be predated less frequently. On the flip side, if small sites are found, they may be predated more efficiently. Multiple sites of various sizes within the island footprint are probably better than 1 large sand pad specifically designed for nesting. Long linear nesting areas can be predated more efficiently. Therefore, irregularly shaped and contoured nesting areas within the island may reduce overall predation rates.

Island Elevation. It is highly desirable to create nesting areas at or above the 10-year flood frequency. Eggs submerged in flood waters for more than 1 hour are rendered unviable. The higher portions of islands, as currently designed for the HREP program, are therefore the more likely areas for successful nesting and should be managed for terrestrial vegetation as described below.

Terrestrial Vegetation. A mosaic of diverse vegetation cover types and open areas, distributed over the higher portions of the constructed islands, would be conducive to turtle nesting success. To the degree necessary, ground cover should be encouraged to insure island stability. However, vegetation too dense may limit turtle access, over shade nests and root-bind hatchlings in the nest. Over story should be limited in some areas on the islands to increase habitat complexity and assist gravid turtles in visually locating appropriate island nesting sites. Breaks in the willow plantings and topsoil placement at irregular intervals, say every 100 to 300 feet, may be required to create the vegetation/opening mosaic required to allow nesting turtles better access to the island interior. Some of the openings should be large enough so that in 15 to 20 years they will still receive 8 to 12 hours of sun a day to meet the thermal requirements to produce female offspring.

Island Nesting Substrate. Islands should have some flat areas rather than just steep or expansive slopes. Nesting substrates would ideally consist of fine sand to medium sand size particles to allow for adequate drainage. Fine-grained particles (silts and clays) placed as topsoil to promote vegetative growth and help stabilize the island, should be incorporated into the underlying sand and not allowed to form a hard, thick, impermeable crust. Again, it may be desirable to leave some portions of the island shoreline and interior topsoil free.

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APPENDIX 9-C

ENGINEERING CONSIDERATIONS

APPENDIX 9-C

ENGINEERING CONSIDERATIONS

Engineering considerations are a broad category of knowledge relating to the physical response, impacts, or properties of islands and associated structures. After goals and objectives for a project have been set, they are considered for identifying actions and measures, establishing design criteria, and developing plans and specifications. Most of the engineering considerations listed here are based on knowledge of river mechanics and sediment transport. They may have been extracted from engineering manuals and adapted to island design or they could represent a summary of engineering analysis that has been done for island projects.

ENGINEERING CONSIDERATION 1 - Shoreline Stabilization

Shoreline stabilization for islands should be designed using the following steps:

1. Determine if stabilization is needed by doing an erosion assessment using the score sheet shown in table 9-C-1. First hand knowledge of erosion problems should supersede this assessment.

Table 9-C-1. Erosion and Stabilization Assessment Worksheet

Erosion & Stabilization Assessment Worksheet

			Location:									
			Shoreline Reach									
Factor	Criteria	Score	1	2	3	4	5	6	7	8	9	10
River Currents	0 to 1 fps	0										
	1 to 3 fps	5										
	> 3 fps	10										
Wind Fetch	0 to 0.5 miles	0										
	0.5 to 1 mile	5										
	> 1 mile	10										
Navigation Effects	Minimal	0										
	Surface Waves	5										
	Tow Prop-Wash	20										
Ice Action	No Ice Action	0										
	Possible Ice Action	5										
	Observed Bank Displacement	10										
Shoreline Geometry	Perpendicular to wind axis	0										
	Skewed to wind axis	2										
	Convex shape	5										
Nearshore Depths	0 to 3 feet	0										
	> 3 feet	3										
Nearshore Vegetation	Persistent, Emerged	0										
	Emergents	1										
	Submerged or no vegetation	3										
Bank Conditions	Hard Clay, Gravels, Cobbles	0										
	Dense Vegetation	1										
	Sparse Vegetation	2										
	Sand & Silt	3										
Local Sediment Source	Upstream Sand Source	0										
	No Upstream Sand Source	1										
		Total Score	0	0	0	0	0	0	0	0	0	0

Total Score >18, Bank Stabilization Needed
Total Score = 12 to 18, Further analysis needed
Total Score < 12, Bank Stabilization Not Needed

Reach Descriptions
Reach 1 -
Reach 2 -
Reach 3 -

2. Decide which of two approaches will be used to deal with erosion. The first approach is to harden the shoreline with additional rock, or in some cases increased vegetation, to make it more resistant to erosion. The second approach is to eliminate or reduce the magnitude of the erosive force so that the shoreline in its existing condition will not erode. This can be done by establishing woody vegetation on the berms, by building offshore structures of rock or wood, or by spacing islands so that wind fetch is kept to an acceptable level.

3. Use the information in table 9-C-2, to determine what type of stabilization to use.

Table 9-C-2. Shoreline Stabilization Designs Recommended for Islands

Erosion Process	Nearshore Bathymetry	Marine Plant Access	Stabilization Design
River Current	Deep (> 3')	Yes	Revetment Vanes
		No	Revetment Vanes
	Shallow (< 3')	Yes	Revetment Vanes Off-Shore Mounds Vegetation
		No	Revetment Vanes Off-shore mounds Vegetation
Waves	Deep (> 3')	Yes	Revetment
		No	Revetment
	Shallow (< 3')	Yes	Groins Rock Wedge Vegetation
		No	Groins Offshore Mound Rock Wedge Vegetation

4. Use figure C-1 to determine berm width. Adequate material must be provided in the berm so that some of the berm material can be eroded during beach formation, and leave at least 15 feet of berm width so that a swath of woody vegetation will protect the main part of the island. Woody vegetation provides rigid stems which protects the main part of the island during floods.

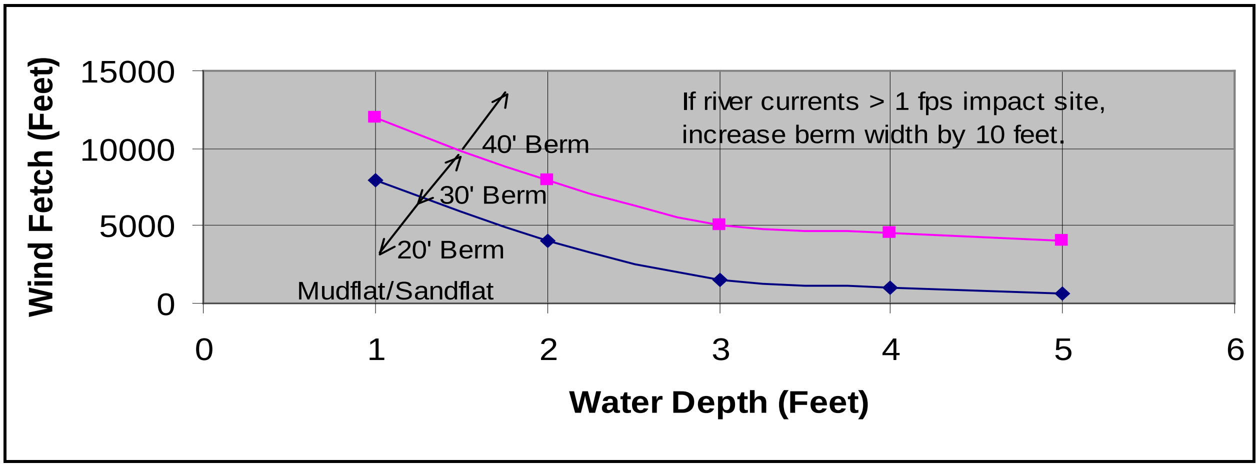

Figure 9-C-1. Berm Width Versus Wind Fetch and Water Depth

5. On shorelines that are extremely sheltered, use vegetative stabilization.

6. On shorelines exposed to significant wave action, rock groins are constructed perpendicular to the berm to prevent long-shore transport of sand. Groins are usually 20 to 40 feet long, have a 3-foot top width, 1V:1.5H side slopes, and are spaced at a distance equal to 6 times the groin length. Offshore rock mounds can be used instead of groins to add diversity to an island shoreline or if shallow depths inhibit access to the shoreline by construction equipment. Rock mounds only need a top elevation at or just above the average water surface to act as wave breaks; however, they are usually constructed to an elevation 2 to 3 feet over the average water surface to account for settlement and sluffing due to wave and ice action. Rock mounds are very expensive to construct.

7. On shorelines where river currents are the primary erosive force, the same berm design as described above can be used except that vanes are used instead of groins. Vanes redirect river currents and move erosive secondary flow cells away from the shoreline. Vanes are 30 to 50 feet long, have a 3-foot top width, 1V:1.5 H side slopes and are spaced at a distance equal to 4 times the vane length. Vanes are angled upstream 30 to 45 degrees with the shoreline and decrease in elevation from 2 feet above the average water surface at the shoreline to 1 foot below the average at the riverward end.

8. The potential for ice action seems to be proportional to the size of the water body. Large backwaters like Lake Onalaska produce the most problems. Ice action can occur due to freeze thaw expansion of the ice pack or due to wind stresses during breakup. If severe ice action occurs in the project area, berm width should be increased, rock size increased, and rock slopes flattened. Groins should not be used, as they are too easily damaged by ice. Photograph 9-C-1 shows Lake Onalaska, Pool 7, where groins were constructed to extend into the water 30 feet. Ice action pushed the rock on to the beach.

Photograph 9-C-1. Ice Damage to Groins Constructed at Lake Onaska, Pool 7

Studies done at the Corps of Engineers' Cold Regions Laboratory recommended maximum rock sizes 2.5 times the average ice thickness and rock slopes of 1V:3H or flatter, if ice conditions are severe. Problems occurred at the Lake Onalaska island project when ice action displaced riprap which had been constructed at a 1V:3H slope. These problems were compounded by the fact that the berms on these islands were only 20 feet wide. Based on this experience, if ice action is expected to be a problem, rock features should be constructed with 1V:4H slopes or flatter and berm widths should be increased to 40 feet or more.

ENGINEERING CONSIDERATION 2 - Reducing Sediment Loads but Increasing Sediment Trap Efficiency

Islands reduce the flow of water and sediment to backwater areas or selected parts of backwater areas. This decreases flow velocities, which is usually a necessary step in improving habitat. However, the trap efficiency of the backwater area sheltered by the island is increased so sediment that does enter is more likely to deposit there. This is compounded by the fact that wind-driven wave action and sediment resuspension, which results in export of sediment from backwaters, is also reduced. In-other-words, an island project may have reduced the sediment input to an area, but the sediment removal mechanisms, river currents and wave action, have also been reduced. Objectives for more recent projects recognize this fact and include features such as rock sills, and strategically placed islands to manage deposition and erosion so that habitat is diversified and sustained. The only way to maintain floodplain depth is to completely eliminate the supply of sediment (which is rarely an option) or to construct islands at a low enough elevation so they are overtopped by annual floods, which potentially could scour sediments from the backwater. This takes advantage of the fact that the sediment-discharge relationship in Pools 1-10 is relatively flat at higher discharges. Figure 9-C-2 shows suspended sediment data at McGregor, Iowa.

This occurs because the sediment transport load is supply-limited, resulting in low sediment concentrations during floods. Sediment concentrations peak near the bankfull discharge and remain steady or sometimes decrease from this point on. By choosing low top elevations, the clean water that occurs at higher discharge is conveyed over the island and through the project area, potentially scouring accumulated sediments carrying them out of the backwater or redistributing them. Recent island projects (Pool 8 Phase II and Polander Lake) have been constructed to lower elevations. The Pool 8 Phase II project included rock sills constructed to about the 2-year flood event and interior islands which force water to move through deeper channels.

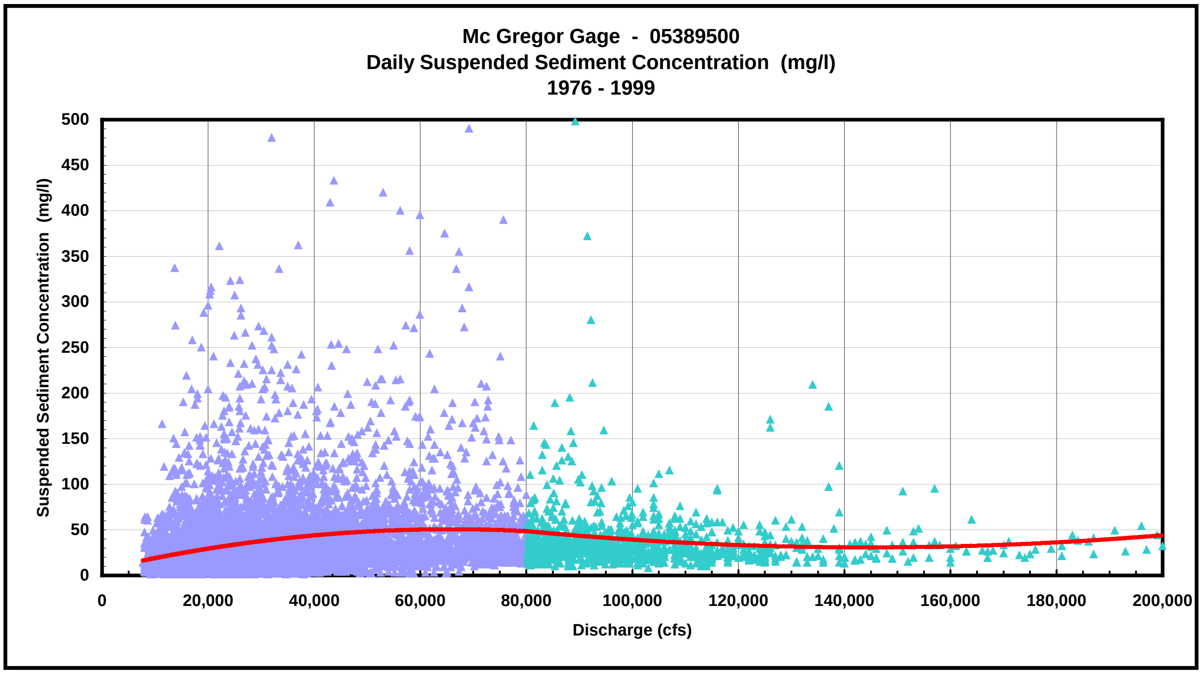

Figure 9-C-2. Data Showing Relatively Low Concentrations That Occur at Higher Discharges (McGregor, IA)

ENGINEERING CONSIDERATION 3 - Island Elevations and Bankfull Flood Elevations in Lower Pools

River restoration efforts usually attempt to establish riverine flow conditions where flow is conveyed in channels for low and moderate flows and significant floodplain flow occurs only after the bankfull flood level is exceeded. Islands, in their most basic form, are the natural levees that separate channels from floodplains. It follows that island height should correspond to bankfull flood levels if the goal is to mimic natural conditions. However, in the lower ends of many of the pools, the elevation that corresponds to a bankfull discharge is often less than the low flow elevation due to the way the locks and dam are operated. See physical attribute number 9 for data.

Constructing an island this low eliminates any chance of maintaining grass cover on the island since woody vegetation quickly takes over. In addition, the operation of construction equipment could be more difficult on a surface this close to the water elevation. For this reason, island elevations are usually higher than bankfull. Low elevation rock sills can be incorporated into the design to increase the amount of floodplain flow. However even these structures usually end up being higher than the bankfull flood event because of habitat considerations in the project area. For instance, creating the low flow conditions for over-wintering fish habitat usually results in the rock sills being set at a higher elevation than bankfull to minimize the chance overtopping during late fall high water events.

ENGINEERING CONSIDERATION 4. Wind-driven Wave Action

Islands effectively reduce wind driven wave action and the resuspension of sediment by waves up to 1 mile downwind of the island (Figure 9-C-3). As wind is deflected up and over an island and its trees, a sheltered zone is created on the downwind side of the island. Research indicates that this zone is anywhere from 10 times the height of the island and its trees (Ford and Stefan, 1980) to 50 times this height (Markfort et al. 2010). The value of this sheltered zone has not been stated in a quantitative fashion; however providing thermal refuge for migrating waterfowl is a desirable outcome of island projects. This sheltered zone should contain aquatic plants, invertebrates, and other forms of food for it to be of value, which is another reason to position islands so they shelter shallow water.

Beyond the sheltered zone, waves start building as wind exerts shear stress on the water surface. Each wave creates an orbital motion in the water column resulting in a bottom velocity and shear stress. If this shear stress exceeds the critical shear stress for particle erosion, sediment is resuspended. Data collected in Weaver Bottoms (Nelson, 1998) indicated a strong relationship between wind and suspended sediment concentrations for low flow conditions but a much weaker relationship as flows approached the bankfull flow event. This transition from Lacustrine to Riverine conditions was due to the increased flow through Weaver Bottoms and higher water levels, which decreased the impacts of wave action on the bottom. A rule of thumb used is that the bottom velocity and shear stress generated by wave action should be less than one half the velocity and shear stress created by flood flows. A wind fetch of 4000 to 5000 feet or less is usually recommended to achieve this. For instance, a wind fetch of 5000 feet, wind speed of 20 mph, and water depth of 3 feet, results in bottom velocities due to wave action of around 0.45 fps (compared to measured velocities during floods that usually approach 1 fps). Other factors such as bathymetry and the location of historic islands usually affect position and spacing as much as the fetch guidance.

While the rule of thumb given above is adequate for initial planning, island spacing and layout should take into account local bathymetry. As the water depth gets shallower, waves have a greater impact on the bottom. To account for this, the bottom shear stress generated by waves should be determined and compared to a critical shear stress for sediment resuspension.

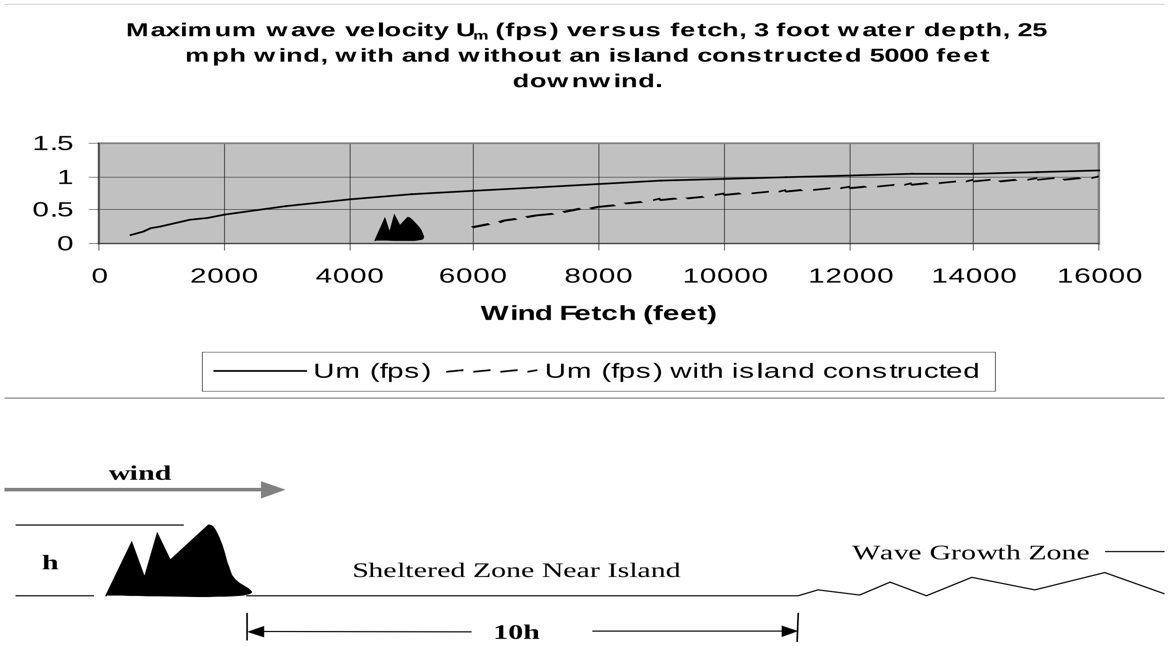

Figure 9-C-3. Wind driven wave velocity and sheltered zone down-wind of an island.

The following equations can be used to calculate wave height, period, and length for deepwater waves, maximum orbital wave velocity, and bottom shear stress. Waves in shallow UMRS impoundments are usually transitional in nature, but the deepwater equations usually do a better job of predicting wave height. Further detail regarding the development of these equations can be found in LTRM Special Report 94-S001 (Chamberlin, 1994).

$$H = .0016\ U_A\ (F/g)^{1/2}$$

$$T = .286\ F^{1/3}\ U_A^{1/3} / g^{2/3}$$

$$L = g\ T^2 / 2\pi$$

$$u_m = \pi H / (T \sinh(2\pi\ d_f / L))$$

$$\tau = \rho\ f\ u_m^2 / 2$$

Where:

- H = wave height (meters)
- U_A = wind speed (meters/second)
- F = wind fetch (meters)
- g = acceleration of gravity (9.82 meters/second)
- T = wave period (seconds)
- L = wave length (meters)
- u_m = maximum orbital wave velocity at the bottom (meters/second)
- d_f = water depth in the floodplain (meters)
- τ = shear stress at the bottom (Newtons/square meter)
- ρ = density of water (Kg/m3)
- f = friction factor (assumed to be .032)

The value of the critical shear stress for sediment resuspension depends on sediment characteristics such as particle size and cohesiveness, and on aquatic vegetation. Usually there is very little information on sediment properties and the amount of aquatic vegetation varies from year to year. A value of .01 psf seems to match conditions in backwater areas fairly well. For instance, using the deep water wave equations, and assuming a wind speed of 20 mph, the wind fetches that result in a bottom shear stress that exceeds the assumed critical shear stress for sediment resuspension of .01 psf are:

Water depth (feet)	1	2	3	4
Deepwater Fetch (feet)	1500	3500	6000	9000

These wind fetch values could be used as a guide in laying out islands.

Figure C-4 (Rogala, 2005) shows the change in wind fetch in lower pool 8 through time. Wind direction data based on historical frequency of occurrence during the open water period was used to create a weighted fetch coverage. The reduction in wind fetch shown over the last three images are due to island construction in lower pool 8 through the EMP. The reduction in fetch from 1989 to 1998 is due to the construction of Phase I and Phase II of the pool 8 islands project. The reduction in fetch from 1998 to 1999 is due to seed island construction. The reduction illustrated from 1999 to 2007 is the expected impact of the Phase III portion of the Pool 8 Island project.

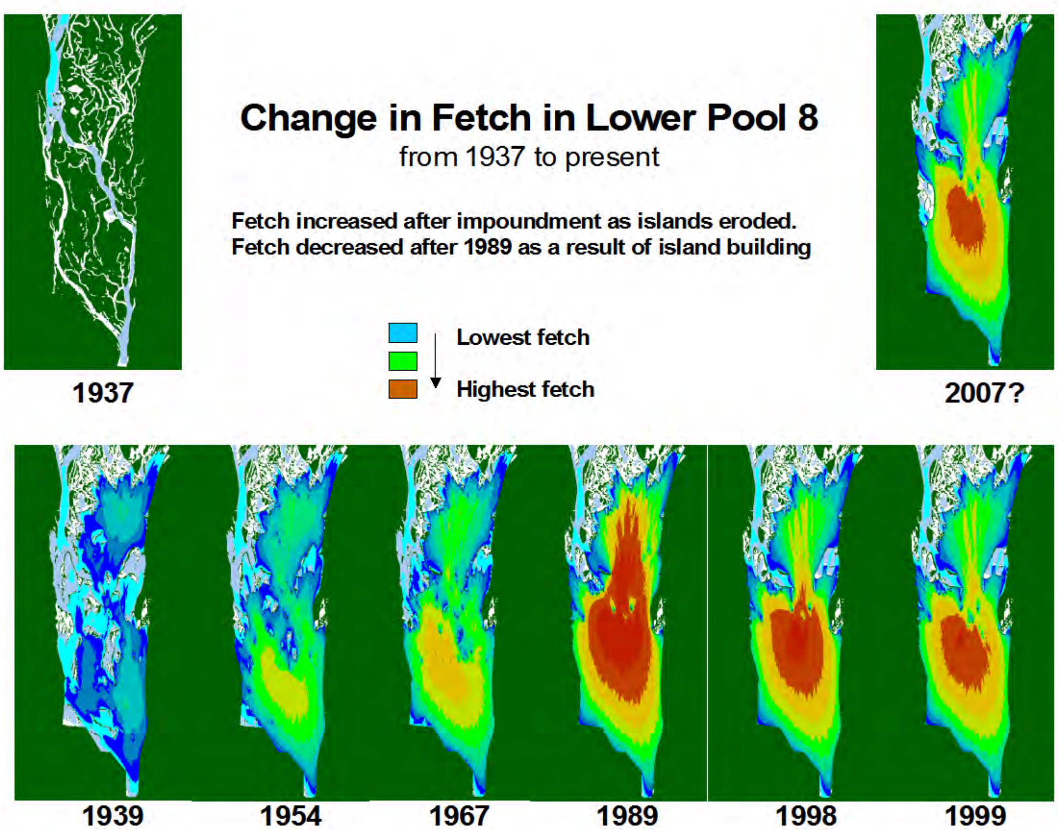

Figure 9-C-4. Changes in Fetch in Lower Pool 8, 1937 to 2007

ENGINEERING CONSIDERATION 5 - Island Width Versus Stability

Lower sections of island that are overtopped more frequently should be wider than higher sections. Typical widths used on previous projects (70 to 200 foot base width, 10 to 100 foot top width) have resulted in stable islands in almost all cases. Some erosion and breaches have formed on islands with top widths of 10 to 40 feet, suggesting that from a stability standpoint, island widths should be greater than 40 feet.

Burrows of animals, mostly muskrats, and subsequent tunnel collapse during spring highwater conditions results in small trenches that may extend up to 20 feet in from the shoreline. The concern is that these trenches could be erosion sites during an overtopping event. This has never been a problem on the wide islands that have been constructed, but it could be a problem if island width were reduced too much.

The present state of island design has focused on meeting aquatic goals and objectives through the construction of the most cost effective and stable island design. However, future island projects that incorporate sand/mudflats, isolated wetlands, and more terrestrial habitat goals and objectives would warrant the construction of islands with larger footprints to meet the terrestrial and other habitat objectives.

ENGINEERING CONSIDERATION 6 - Beach Formation Process

When sand is placed for the island base, two wind-driven processes begin acting. The first is littoral drift, which is the process of sand moving down a shoreline in response to the angle that waves approach a shoreline from the predominant wind direction. Groins are usually constructed to stop this process, resulting in the scalloped shoreline shape. Photograph 9-C-2 shows Grassy Island a couple of months after construction. Wave action and littoral drift have caused the scalloped shape seen here. Sand is eroded from the area between each set of groins and deposits near the groin.

The second process is beach formation, which results from a combination of offshore transport of sand and from berm erosion due to wave action. Surveys of island shorelines indicate that a beach with a slope of 1V:8H to 1V:12H will eventually be created. The initial berm profile and the final profile are illustrated in figure 9-C-5. Enough material must be placed in the berm so that after the beach formation process has occurred at least 20 feet of berm will remain upon which willows and other woody vegetation can grow. As an example, if the water depth is 3 feet and the beach slope is 1V:10H, a 30 foot wide beach will form. Roughly half of the berm will erode during this process. So with 15 feet of berm erosion, the initial berm width should have been 35 feet for 20 feet of berm to remain.

Photograph 9-C-2. Pool 8, Phase I, Stage II, Grassy Island

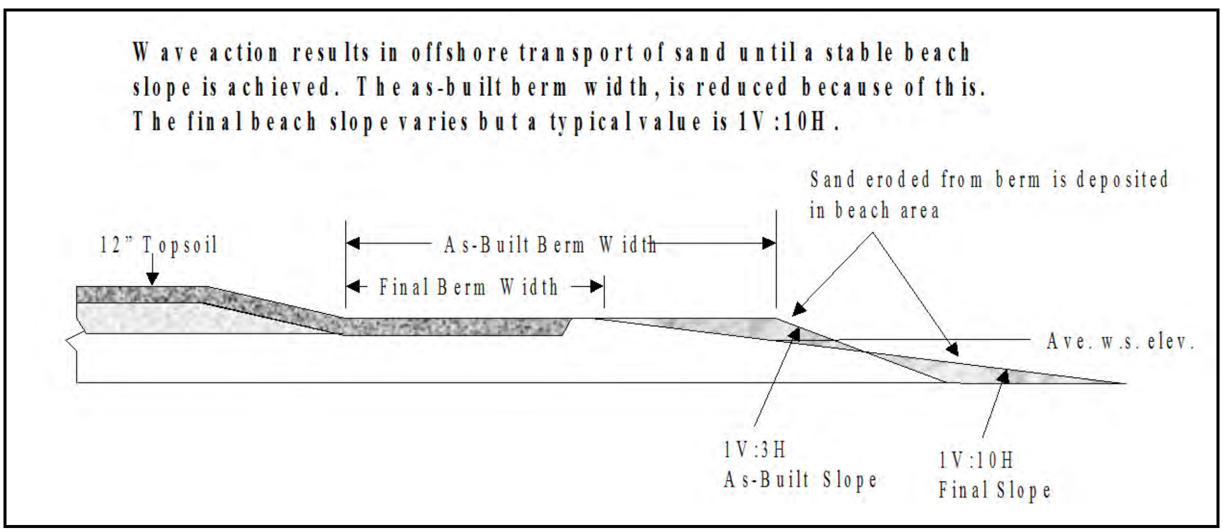

Figure 9-C-5. Reshaping of the Islands Shoreline Due to Wave Action

ENGINEERING CONSIDERATION 7 - Wood Species for Biotechnical Stabilization

Placing logs along island shorelines or incorporating them into shoreline stabilization structures is desirable from the standpoint of habitat (fish structure, loafing structure and substrate) and aesthetics. Logs with a high specific weight and high decay resistance are desirable since they resist the buoyant forces exerted on them and they will last longer. An excellent reference on large woody debris structures is Shields, et al. (2004). This reference discusses in detail design procedures, costs, and successes of woody debris structures. The information in table 9-C-3 on wood density and decay resistance was developed by the St. Paul District's Natural Resources Office. Black Locust is the most desirable species since it is relatively heavy, decay resistant, and is an undesirable non-native species that is frequently harvested because it tends to dominate forests once it becomes established.

Table 9-C-3. Properties of Wood (Urich, 2005)

Species	Weight per Standard Cord (pounds)	Weight per Cubic Foot (green)	Decay Resistance
Ash, white	4300	48	Low
Aspen			Low
Black cherry	4000	45	High
Black locust	5200	58	Exceptionally High
Black walnut	5200	58	High
Cottonwood	4400	49	Low
Elm	5000	54	Low
Hackberry	4500	50	Low
Hickory	5700	63	Low
Honeylocust	5500	61	Moderate
Red Cedar	3300	37	High
Silver maple	4300	45	Low
Red oak	5700	64	Low
White oak	5600	63	High

From the standpoint of longevity, it is desirable to place the logs so that they are either above or below the water surface the majority of the time to avoid decay associated with wetting and drying. However, the guidance on habitat loafing structures (habitat parameter 5) should be used to optimize log placement.

ENGINEERING CONSIDERATION 8 - Seepage Through Rock Structures

Excessive seepage through the voids in rock structures is a concern because of the potentially negative impacts on over-wintering fish habitat. An impervious fabric was included in the rock sills at the Pool 8, Phase II project to reduce seepage, however this nearly doubled the cost of these rock sills. Natural plugging of the voids in rock structures has been documented in the past, however there are other cases where seepage seems to occur for years after the structure is constructed. There does not seem to be a consistent set of lessons learned regarding seepage, so it is something that design teams must take into account on a case-by-case basis.

ENGINEERING CONSIDERATION 9 - Displacement of Sediments

Displacement (or rapid settlement, which occurs during construction) occurs on every project to some extent. The Corps' standard method of measuring displacement is settlement gages, however these don't work for islands built hydraulically because they are always tipped over by the mud wave in front of the sand. At the Trempealeau National Wildlife Refuge (NWR), which involved construction of a dike in open water similar to what is done for islands, displacement of 1.25 feet was measured using post construction borings. The method of hydraulic placement of sand had to be altered to reduce the size of the mud-wave, which inhibited continued placement of sand. The technique ultimately used, involved placing the sand in a wedge-shaped fashion.

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APPENDIX 9-D

ISLAND DIMENSIONS, COSTS, AND STATISTICS

APPENDIX 9-D

ISLAND DIMENSIONS, COSTS, AND STATISTICS

Table 9-D-1 provides design dimensions for constructed island projects. The variables “a” through “f” correspond to those shown in figure 9 5 in Chapter 9, *Island Design*. The top elevation is listed and the corresponding flood that would overtop that elevation. Generally, top elevations have decreased with each successive project and the variability of elevations has increased.

Table 9-D-2 provides information on the thickness and gradation (where available) of the topsoil and random fill layers on islands.

Table 9-D-3 lists the length of various types of shoreline stabilization used on islands that have been constructed. Although there is significant variation from project to project, a typical distribution is 20-percent riprap, 40-percent biotechnical, and 40-percent vegetative. More recent projects tend to have less riprap and more use of biotechnical and vegetative stabilization.

The cost of several island projects, are shown in table 9-D-4. Based on the cost of the Pool 8, Phase III project the typical cost for earth islands is $460 per linear foot or $180,000 per acre, however many of the islands included additional habitat features such as mud flats, sand flats, turtle nesting mounds, and loafing structures.

Material costs for earth islands are given in table 9-D-5. Granular fill, fines, and rock account for 75 to 95-percent of the cost of earth islands. Establishing turf and planting willows or trees usually account for less than 10-percent of the costs.

Table 9-D-1. Island Cross Section Dimensions [1]

Project	a (ft)	b (ft)	c (ft)	d (ft)	e (ft)	f (ft)	Height above Normal Pool (ft)	Corresponding Flood (TOR)	Island Length and Reach Description (ft)	Year
Weaver Bottoms	0	32	100	32	0	164	8	80-yr	8700	1986
Lake Onalaska	0	18	50	9	20	100	6	20-yr	3900, 3 islands at 1300' each	1989
Pool 8, Phase I, Stage 1, Horseshoe Island	0	20	50	30	30	130	4	10-yr	2100, from head down each leg	1989
	0	20	75	30	30	155	4	10-yr	800, middle west leg	1989
	0	20	30	40	0	90	4	10-yr	600, lower west leg	1989
Bertom McCartney										1992
Pool 8, Phase I, Stage 2, Boomerang Island	30	12	50	12	30	134	3.8	10-yr	7000	1992
	20	12	50	12	20	114	3.8	10-yr	700, several reaches	1992
	30	10	50	40	0	130	3.8	10-yr	500, large fines section	1992
	0	25	30	25	0	80	5	17-yr	500, lower Horseshoe Island.	1992
Pool 8, Phase I, Stage 2, Grassy Island	0	6	50-150	6	0	62-162	2	5-yr	900	1992
Pool 9, Islands A & B[2]	na	3.4	5	3.4	na	12	1.5	1.6-yr	3800	1994
Pool 9, Islands D[2]	na	2	5	2	na	9	.5	1.3-yr	2900	1994
Polander Lake, Stage 1, Island 2[2]	na	9	4	9	na	22	2	1.8-yr	1100	1994
Willow Island	30	25	10	21	0	86	7	10-yr	2800	1995
	0	17	10	21	0	48	7	10-yr	900, riprap reach	1995
Peoria Lake Islands	0		50		0		8		5280	1996
Swan Lake, Illinois River	0	45	25	45	0	115	5		9 islands 180' to 500' long	1996
Pool 8, Phase II, Eagle Island	33	13	50	13	33	142	4	10-yr	2800	1999
Pool 8, Phase II, Slingshot Island	33	8	33	8	20	102	3	7-yr	3300, Upper Slingshot Island	1999
	33	7	33	7	33	113	2.7	6-yr	1200, Middle Slingshot Island	1999
	33	3	33	3	33	105	2	5-yr	900, Lower Slingshot Island	1999
Pool 8, Phase II, Interior Islands,	33	13	33	13	20	112	4	10-yr	2400	1999
Pool 8, Phase II Rock Sills*	na	6	13	3	na	22	1	2.5-yr	2500	1999
Polander Lake, Stage II	40	17.5	20	17.5	30	125	5	4-yr	3800	2000
	40	27.5	20	27.5	30	145	7	8-yr	1200	2000
Polander Lake, Stage II, Interior Islands	20	20	20	12	20	92	3.5	2.5-yr	4200	2000
Tilmont Lake			33			55			540	2002
Pool 11 Sunfish Lake									5150	2004
Pool 11, Mud Lake									9728	2005
Spring Lake, Bullrush Island	20	5	40	5	45	115	3	8-yr	2400	2005
Spring Lake, Deep Hole Island	20	10	45	10	30	115	4	15-yr	850	2005
Spring Lake, Deep Hole Island	40	0	65	0	40	145	2	6-yr	1400	2005

Table 9-D-1. Island Cross Section Dimensions [1]

Project	a (ft)	b (ft)	c (ft)	d (ft)	e (ft)	f (ft)	Height above Normal Pool (ft)	Corresponding Flood (TOR)	Island Length and Reach Description (ft)	Year
Spring Lake, Deep Hole Island	0	0	60	0	0	60	2.5	7-yr	1250	2005
Spring Lake, Snipe Island	0	0	115	0	0	115	2.5	7-yr	2050	2005
Pool 8, Phase III, Horseshoe I. (N1)	Flat Top					40	0.3		3650	2008
Pool 8, Phase III, Canthook I., S. end	20	7.5	40	7.5	45	120	2.5		1150	2008
Pool 8, Phase III, Canthook I., N. end	20	10	40	10	45	125	3		1317	2008
Pool 8, Phase III, Raft I., S. end	30	10	40	10	45	135	3		2225	2008
Pool 8, Phase III, Raft I., Middle	Flat Top					162	1		2000	2008
Pool 8, Phase III, Raft I., N. end	20	7.5	40	7.5	45	120	2.5		2625	2008
Pool 8, Phase III, Raft I., Leg	Flat Top					105	.5		925	2008
Pool 8, Phase III, Dabbler I., N end	Flat Top					95	1		750	2008
Pool 8, Phase III, Dabbler I., N tip	20	10	40	10	30	110	3		1050	2008
Pool 8, Phase III, Dabbler I., S end	Flat Top					95	.5		1750	2008
Pool 8, Phase III, Dabbler I., leg	Flat Top					95	.5		750	2008
Pool 8, Phase III, Cygnet I.	Flat Top					130	.5		790	2008
Pool 11, Mud Lake Island	Flat Top									2009
Pool 8, Phase III, Broken Bow I	Flat Top					120	1		2260	2008
Pool 8, Phase III, Snake Tongue, W.	45	10	40	10	45	150	3		1250	2008
Pool 8, Phase III, Snake Tongue, E.	Flat Top					150	1		1500	2008
Pool 8, Phase III Snake Tongue, Leg	Flat Top					150	.5		900	2008
Pool 8, Phase III Island C2, West	Flat Top					150	1		2560	2010
Pool 8, Phase III Island C2, East	Flat Top					150	1		660	
Pool 8, Phase III Island C3	Flat Top					115	1		1500	2010
Pool 8, Phase III, Island C4, W. leg	45	12	40	12	20	130	3.5		1425	2010
Pool 8, Phase III, Island C4, E. leg	Flat Top					150	1		1475	2010
Pool 8, Phase III, Island C5	Flat Top					115	1		1200	2010
Peoria Island										2010
Pool 8, Phase III, Raft I., N2	30	15	40	15	45	145	4		1170	2011
Pool 8, Phase III, Island C6	Flat top					130	1		800	2011
Pool 8, Phase III, Island C7	Flat Top					130	1		660	2011
Pool 8, Phase III, Island C8, W. Leg	45	10	40	10	45	150	3		2145	2011
Pool 8, Phase III, Island C8, E. Leg	Flat Top					150	1		1855	2011

[1] Elevations are NGVD, 1912 adj. Dimensions are in feet.
[2] These islands were constructed entirely of rock.

Table 9-D-2. Topsoil and Random Fill Thickness and Gradations

Project/Island	Island Length (ft)	Topsoil Thickness (inches) and Minimum Percent Fines	Random Fill Thickness (inches) and Minimum Percent Fines	Construction Completed
Weaver Bottoms	8700	6		1986
Lake Onalaska	3900 (1300 each)	6 to 12		1989
Pool 8, Phase I, Stage 1, Horseshoe Island	3450	4 to 8		1989
Pool 8, Phase I, Stage 2, Boomerang Island	8175	48, 50-percent fines		1992
Pool 8, Phase I, Stage 2, Horseshoe Island	490	24 to 36		1992
Pool 8, Phase I, Stage 2, Grassy Island	900	6 to 12		1992
Bertom McCartney Island	2,700	N/A	120, in situ materials	1993
Willow Island	3700	6		1995
Peoria Lake	18,586	N/A	48, in situ materials, uncompacted	1997
Pool 8, Phase II, Eagle Island	2800	12, 40-percent fines	48, 5-percent fines	1999
Pool 8, Phase II, Upper & Middle Slingshot Island	4440	12, 40-percent fines	36, 5-percent fines	1999
Pool 8, Phase II, Lower Slingshot Island	910	12, 40-percent fines	24, 5-percent fines	1999
Pool 8, Phase II, Interior Islands	2350	12, 40-percent fines	48, 5-percent fines	1999
Polander Lake	5300	12, 40 to 70-percent fines		2000
Tilmont Lake Peninsula	540	N/A	60, in situ materials	2002
Pool 11, Sunfish Lake Island	5,144	N/A	100, in situ materials	2005
Spring Lake, Water Snake Island	1800	12		2005
Spring Lake, Bulrush Island	2400	12		2005
Spring Lake, Snipe Island	2050	12		2005
Spring Lake, Deep Hole Island	3750	12		2005
Pool 8, Phase III, Horseshoe Island (N1)	3650	6		2008
Pool 8, Phase III, Canthook Island	2467	12		2008
Pool 8, Phase III, Raft Island	4850	12		2008
Pool 8, Phase III, Raft Island, Middle	2000	9		2008
Pool 8, Phase III, Dabbler Island, N end	1000	12		2008
Pool 8, Phase III, Dabbler Island, S end	2450	9		2008
Pool 8, Phase III, Dabbler Island, Middle	750	6		2008
Pool 8, Phase III, Cygnet Island	790	6		2008

Table 9-D-2. Topsoil and Random Fill Thickness and Gradations

Project/Island	Island Length (ft)	Topsoil Thickness (inches) and Minimum Percent Fines	Random Fill Thickness (inches) and Minimum Percent Fines	Construction Completed
Pool 11, Mud Lake Island	9,728	N/A	100, in situ materials	2006
Pool 8, Phase III, Broken Bow I	2260	9		2008
Pool 8, Phase III, Snake Tongue, W.	1250	12		2008
Pool 8, Phase III, Snake Tongue, E.	1500	12		2008
Pool 8, Phase III Snake Tongue, Leg	900	6		2008
Pool 8, Phase III Island C2	3220	9		2010
Pool 8, Phase III Island C3	1500	9		2010
Pool 8, Phase III, Island C4, W. leg	1425	12		2010
Pool 8, Phase III, Island C4, E. leg	1475	9		2010
Pool 8, Phase III, Island C5	1200	9		2010
Peoria Island	2,800	N/A	120, contained in geotextile containers	Est. 2013
Pool 8, Phase III, Raft Island, N2	1170	12		2011
Pool 8, Phase III, Island C6	800	9		2011
Pool 8, Phase III, Island C7	660	9		2011
Pool 8, Phase III, Island C8, W. Leg	2145	12		2011
Pool 8, Phase III, Island C8, E. Leg	1855	9		2011

Table 9-D-3. Shoreline Stabilization Length, and Percent of Total Length Used on Island Projects

Island	Shoreline Length (ft)	Riprap Stabilization Length (ft)	Riprap Stabilization % of Length	Bio-Geo Stabilization Length (ft)	Bio-Geo Stabilization % of Length	Vegetative Stabilization Length (ft)	Vegetative Stabilization % of Length	Year Constructed
Weaver Bottoms	17400	2180	12.5	5670	32.6	9550	54.9	1986
Lake Onalaska	9540	7370	77.3	1280	13.4	890	9.3	1989
Pool 8, Phase 1 Horseshoe	6900	600	8.7	0	0.0	6300	91.3	1989
Pool 8, Phase 1 Boomerang	17330	1885	10.9	4600	26.5	10845	62.6	1992
Pool 8, Phase 1 Grassy	2600	780	30.0	1100	42.3	720	27.7	1992
Willow Island	3700	900	24.3	1700	45.9	1100	29.7	1995
Pool 8, Phase II, Eagle Island	5660	460	8.1	3450	61.0	1750	30.9	1999
Pool 8, Phase II, Slingshot Island	10800	600	5.6	7520	69.6	2680	24.8	1999
Pool 8, Phase II, Interior Islands	4700	800	17.0	3900	83.0	0	0.0	1999
Polander Lake, Stage 2 Barrier Islands	10,000	1000	10.0	4600	46.0	4400	44.0	2000
Polander Lake, Stage 2 Interior Islands	4210	120	2.9	0	0.0	4090	97.1	2000
Tilmont Lake Peninsula	1080					1080	100.0	
Pool 11, Sunfish Lake Island	10,463	3,083	29.5	0	0.0	7380	70.5	2005
Pool 11, Mud Lake Island	19,456	3,802	19.5	0	0.0	15654	80.5	2006
Spring Lake, Water Snake Island	3600	1800	50.0	600	16.7	1200	33.3	2005
Spring Lake, Bulrush Island	4800	925	19.3	2400	50.0	1475	30.7	2005
Spring Lake, Snipe Island	4100	630	15.4	3470	84.6	0	0.0	2005
Spring Lake, Deep Hole Island	7500	0	0.0	7500	100.0	0	0.0	2005
Pool 8, Phase III, Horseshoe Island (N1)	7300	1650	22.6	2000	27.4	3650	50.0	2007
Pool 8, Phase III, Canthook Island	4934	280	5.7	2187	44.3	2467	50.0	2008
Pool 8, Phase III, Raft Island	15550	350	2.3	7425	47.7	7775	50.0	2008
Pool 8, Phase III, Dabbler Island,	8700	350	4.0	4000	46.0	4350	50.0	2008
Pool 8, Phase III, Cygnet Island	1580	0	0.0	790	50.0	790	50.0	2008
Pool 8, Phase III, Broken Bow I	4520	0	0.0	2260	50.0	2260	50.0	2008
Pool 8, Phase III, Snake Tongue,	7300	0	0.0	7300	100.0	0	0.0	2008
Pool 8, Phase III , Island C2	6440	310	4.8	5010	77.8	1120	17.4	2010
Pool 8, Phase III , Island C3	3000	0	0.0	1500	50.0	1500	50.0	2010
Pool 8, Phase III, Island C4, W. leg	5800	325	5.6	3075	53.0	2400	41.4	2010
Pool 8, Phase III, Island C5	2400	0	0.0	1200	50.0	1200	50.0	2010
Peoria Island	2800	1000	35.7	1800	64.3	0	0.0	Est 2013
Pool 8, Phase III, Raft Island, N2	2340	0	0.0	2340	100.0	0	0.0	2011
Pool 8, Phase III, Island C6	1600	0	0.0	1600	100.0	0	0.0	2011
Pool 8, Phase III, Island C7	1320	0	0.0	1320	100.0	0	0.0	2011
Pool 8, Phase III, Island C8, West and East Leg	8000	0	0.0	8000	100.0	0	0.0	2011
Peoria Lake	18586	0	0.0	0	0.0	18586	100.0	1997
Bertom McCartney Island	2700	0	0.0	0	0.0	2700	100.0	1993
PERCENT ALL PROJECTS			**12.5**		**40.0**		**47.4**	

Table 9-D-4. Costs of Island Projects [1]

Project	Year Constructed	Feature	Length (feet) and Area (acres)	Cost	Cost/Foot Cost/Acre
Pool 8, Phase I, Stage 2	1992	Earth Islands	9,600	$1,456,000	$151
Pool 8, Phase II	1999	Earth Islands	10,600	$1,755,000	$165
		Rock Sills	2,500	$722,000	$288 *
		Seed Islands	1,280	$169,000	$132
		Total Cost		$2,646,000	
Polander Lake, Stage 2	2000	Earth Islands	9,200	$1,897,000	$206
Sunfish Lake, Pool 11	2003	Earth Islands	8,724	$3,972,600	$455
Spring Lake, Pool 5	2005	Earth Islands	10,065 ft 36.1 acres	$4,230,600	$300 average of Islands 1,2,3,4
Mud Lake, Pool 11	2005	Earth Islands	10,804	$3,482,919	$322
Pool 8, Phase III, Stage 1	2006	E1 (cobble) E2 (log/rock) E3 (sand)	600 760 1,151	$303,000 $147,000 $255,000	$505 $194 $221
Pool 8, Phase III, Stage 2B, Islands W1, W2, W3, W4, N7, N8	2008	Earth Islands	23,600 ft 58 acres	$10,329,000	$437/ft $178,000/acre
Pool 8, Phase III, Stage 3A, Islands C2, C3, C4, C5	2010	Earth Islands	8,960 ft 38.6 acres	$4,851,000	$474/ft $157,000/acre
Pool 8, Phase III, Stage 3A, Islands C2A, C2B, C2C	2010	C2A (seed I) C2B (seed I) C2C (log/rock)	200 220 160		$270 $281 $253
Pool 8, Phase III, Stage 3B, Islands C6, C7, C8	2011	Earth Islands	7,160 ft 17 acres	$3,360,000	$469/ft $198,000/acre

[1] Costs per foot and cost per acre for Spring Lake, Mud Lake, Sunfish Lake, and Pool 8 Phase III were obtained from the USFWS.

Table 9-D-5. Material Costs For Earth Islands [1]

Island Project	Earth Island Cost ($1000)	Granular Fill	Fines	Random Fill	Rock Shore Protection	Turf	Plantings - willows, trees, shrubs	Mob/ Demob	Geo-textile	Loafing Structure
Pool 8, Phase I Stage 2	1,456	$5.46/yd^3 855 59%	$6.95/yd^3 389 27%	N.A.	$14.50/t 140 10%	$1250/ac 22 1.5%	20 1.1%	[2]	2.50/yd^2 18 1.2%	N.A.
Pool 8, Phase II	1,707	$2.88/yd^3 501 29 %	$4.70/yd^3 238 14 %	N.A.	$33/ton 550 32%	$2491/ac 47 3 %	148 9%	186 11%	3.85/yd^2 37 2%	N.A.
Polander Lake, Stage 2	1,819	$2.90/yd^3 518 28%	$17.50/yd^3 538 30%	$2.55/yd^3 93 5%	$35/ton 372 20%	$1990/ac 31 2%	53 3%	177 10%	3.40/yd^2 14 1%	14 1%
Peoria Lake				$2.00/yd^3						
Pool 11 Islands				$10.90/yd^3						
Pool 8, Phase III, Stage 3A [3]	5,500									
Pool 8, Phase III, Stage 3B [3]	3,400									

[1] In each box the top number is the unit costs, the middle number is the total dollar amount paid the contractor for each material (in thousands of dollars), and the bottom number is percentage of the total earth island cost paid for each type of material. Dollar amounts are based on the base contract amounts for earth islands with adjustments made for modifications during construction. These values were obtained from the contract bid forms found in the final contract report for each project. Expenditures not related to earth island construction (e.g. seed island construction) are not included. No adjustments were made due to inflation to obtain a present value.

[2] The Pool 8, Phase I, Stage 2 contract had no separate bid item for mobilization and these costs are most likely reflected in the higher sand granular fill unit cost.

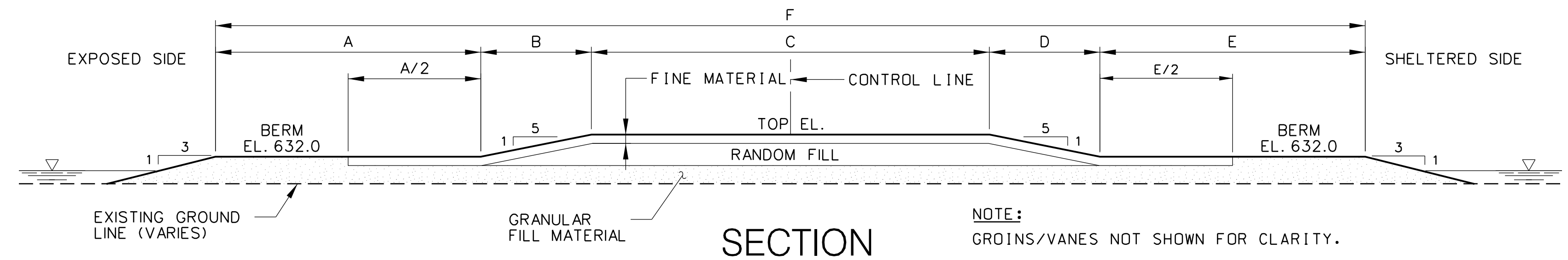
[3]Phase III data is from Scott Baker presentation given on Feb22 at St. Paul District Office. For stage 3A, 340,000 yd3 of granular, and 37,000 yd3 of fines. For stage 3B 165,000 yd3 granular, 16,000 yd3 fines, 20,000 tons of rock (16,000 tons for the rock sill)

Shoreline stabilization costs include earth fill (granular and fines) for the berm, rock, and the cost of willow plantings.

UPPER MISSISSIPPI RIVER RESTORATION
ENVIRONMENTAL MANAGEMENT PROGRAM
ENVIRONMENTAL DESIGN HANDBOOK

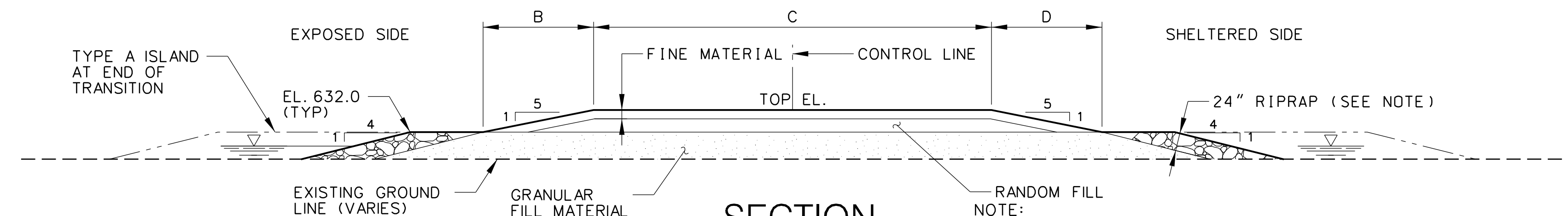
APPENDIX 9-E

STANDARD DETAILS



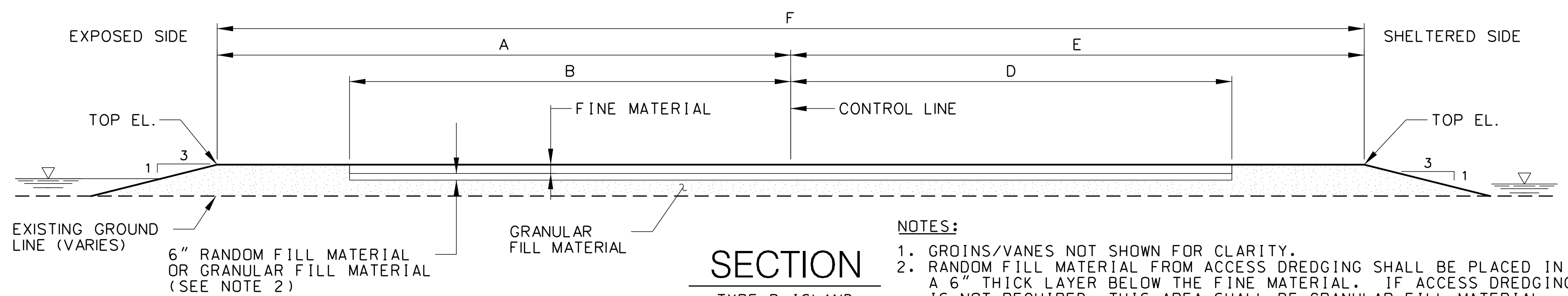
SECTION
TYPE A ISLAND

NOTE:
GROINS/VANES NOT SHOWN FOR CLARITY.



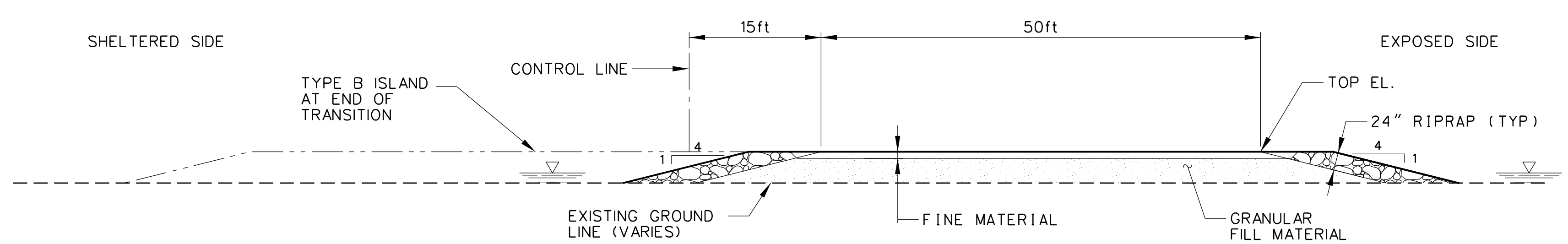
SECTION
TYPE A-1 ISLAND

NOTE:
THE INCLUSION OF RIPRAP AND ITS LOCATION WILL VARY BY ISLAND. SEE INDIVIDUAL ISLAND PLANS FOR LOCATION.



SECTION
TYPE B ISLAND

NOTES:
1. GROINS/VANES NOT SHOWN FOR CLARITY.
2. RANDOM FILL MATERIAL FROM ACCESS DREDGING SHALL BE PLACED IN A 6" THICK LAYER BELOW THE FINE MATERIAL. IF ACCESS DREDGING IS NOT REQUIRED, THIS AREA SHALL BE GRANULAR FILL MATERIAL.



SECTION
TYPE B-1 ISLAND
(SECTION AT END OF ISLAND)

NOTE:
GROINS/VANES NOT SHOWN FOR CLARITY.

US Army Corps of Engineers
ST. PAUL DISTRICT

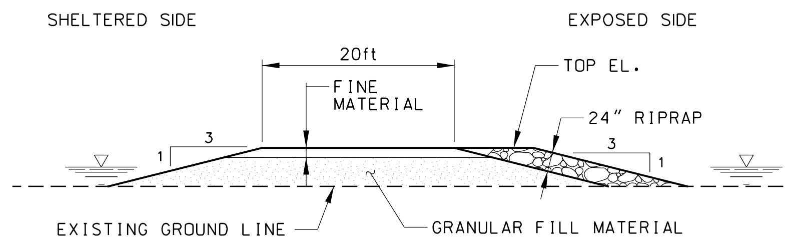
U.S. ARMY CORPS OF ENGINEERS
ST. PAUL DISTRICT
ST. PAUL, MINNESOTA

DESIGNED BY: RGF/JSH/DDA
DWN BY: RGF
CKD BY: JBM
SUBMITTED BY:
SOLICITATION NO.: W912ES-13-B-0001
CONTRACT NO.:
PLOT SCALE: 1"=10'
PLOT DATE: No
FILE NUMBER:
SIZE: D
FILE NAME:

HABITAT REHABILITATION AND ENHANCEMENT
MISSISSIPPI RIVER
ISLAND DESIGN MANUAL STANDARD DETAILS

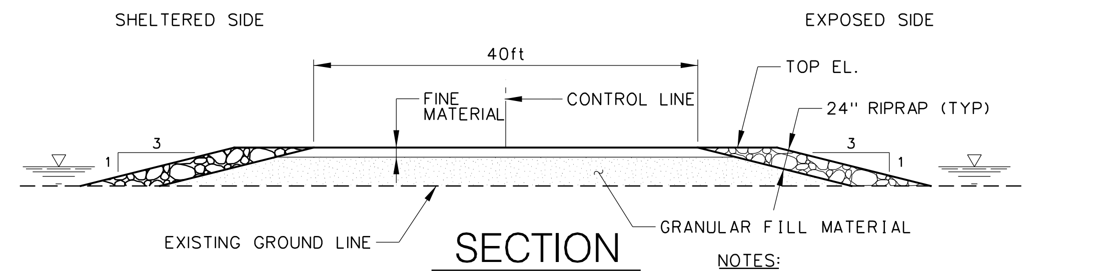
ISLAND TYPES A & B

SHEET IDENTIFICATION
PLATE I



SECTION

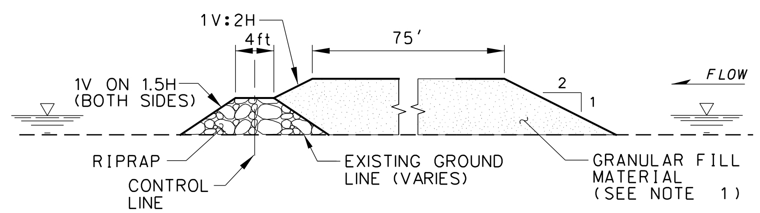
TYPE C ISLAND



SECTION

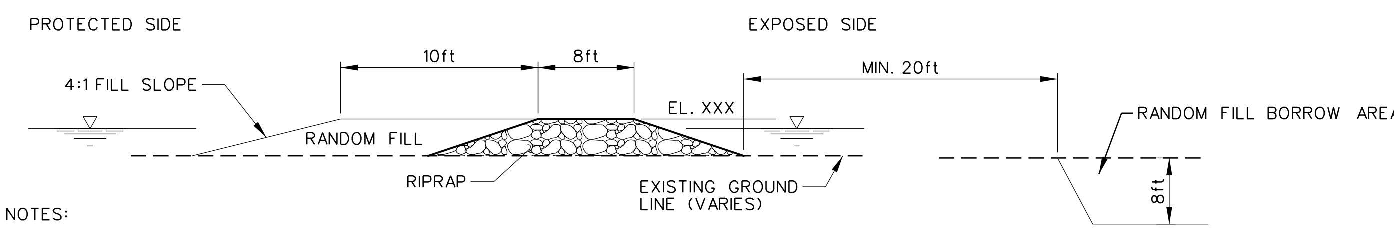
TYPE C ISLAND
(SECTION AT END OF ISLAND)

NOTES:
1. GROINS/VANES NOT SHOWN FOR CLARITY.



SECTION

TYPE D - SEED ISLAND

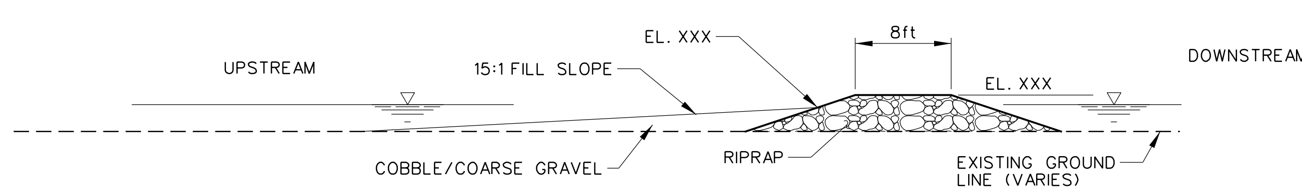


NOTES:

1. ALL ROCK FILL SLOPES SHALL BE 1V:2H.

SECTION

TYPE E ISLAND



SECTION

TYPE F ISLAND
FISH SPAWING HABITAT

NOTES:

1. ALL ROCK FILL SLOPES SHALL BE 1V:2H.

US Army Corps of Engineers
ST. PAUL DISTRICT

MARK	DESCRIPTION	DATE	APPR

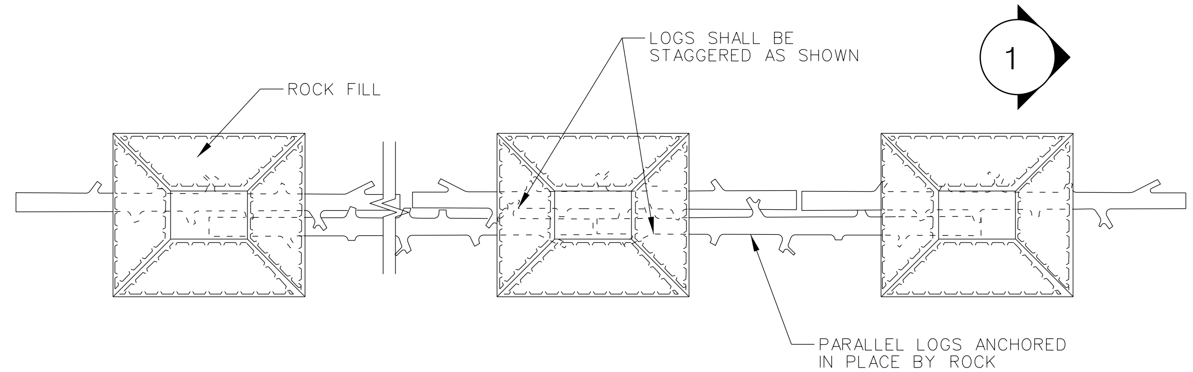
U.S. ARMY CORPS OF ENGINEERS
ST. PAUL DISTRICT
ST. PAUL, MINNESOTA

DESIGNED BY: RGF/JSH/DDA
DWN BY: RGF
CKD BY: JBM
SUBMITTED BY:
PLOT SCALE: 1"=10'
PLOT DATE: No
SIZE: D
FILE NAME:
DATE:
SOLICITATION NO.: W912ES-13-B-0001
CONTRACT NO.:
FILE NUMBER:

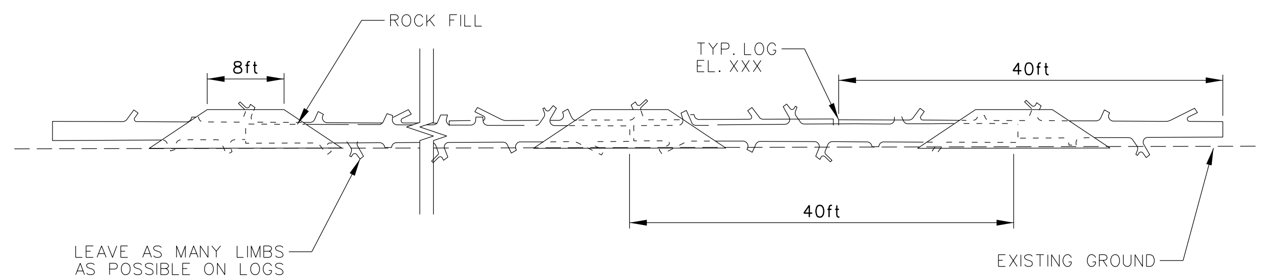
HABITAT REHABILITATION AND ENHANCEMENT
MISSISSIPPI RIVER
ISLAND DESIGN MANUAL STANDARD DETAILS

ISLAND TYPES C, D, E & F

SHEET IDENTIFICATION
PLATE 2

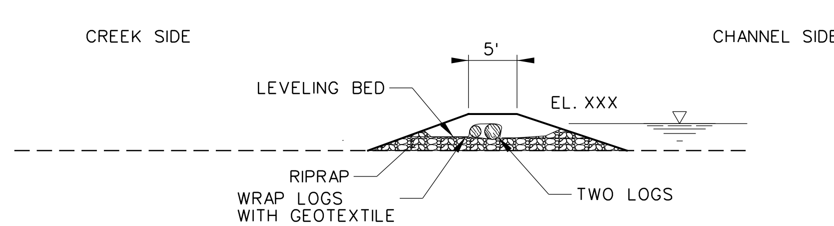


PLAN VIEW



ELEVATION

ROCK/LOG ISLAND



1 SECTION

ROCK/LOG ISLAND

NOTES:

1. LOGS SHALL BE 40' LONG AND 2' MIN DIA. AT BASE TRIM LIMBS AS NECESSARY TO ALLOW LOG PLACEMENT TO THE CORRECT ELEVATION. A ROCK FILL LEVELING BED SHALL BE USED TO BRING LOGS TO THE DESIGN ELEVATION. ROCK THICKNESS WILL VARY.

US Army Corps of Engineers®
ST. PAUL DISTRICT

MARK	DESCRIPTION	DATE	APPR.

MARK	DESCRIPTION	DATE	APPR.

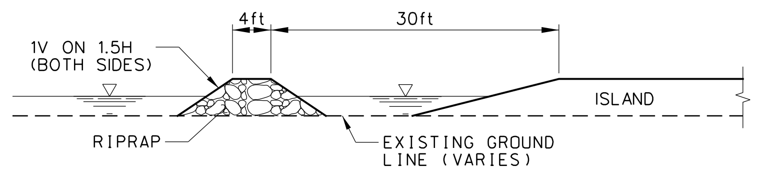
U.S. ARMY CORPS OF ENGINEERS
ST. PAUL DISTRICT
ST. PAUL, MINNESOTA

DESIGNED BY: RGF/JSH/DDA
DATE:
DWN BY: RGF
CKD BY: JBM
SOLICITATION NO.: W912ES-13-B-0001
SUBMITTED BY:
CONTRACT NO.:
PLOT SCALE: 1"=10'
PLOT DATE: No
FILE NUMBER:
SIZE: D
FILE NAME:

HABITAT REHABILITATION AND ENHANCEMENT
MISSISSIPPI RIVER
ISLAND DESIGN MANUAL STANDARD DETAILS

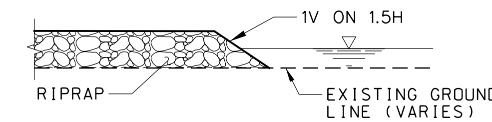
ROCK/LOG ISLAND

SHEET IDENTIFICATION
PLATE 3

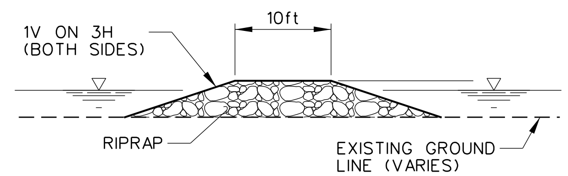


SECTION
ROCK MOUND ALONG ISLAND

0 10' 20'

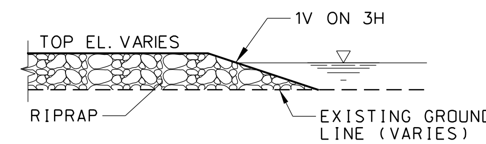


LONGITUDINAL SECTION
THRU ROCK MOUND AT END (TYP)



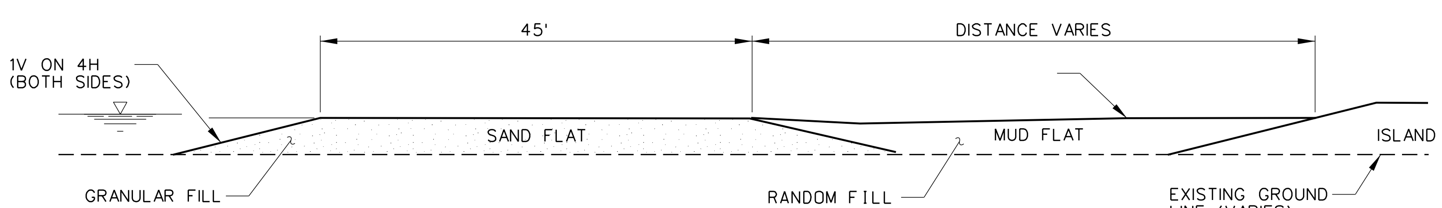
SECTION
ROCK SILL

0 10' 20'



LONGITUDINAL SECTION
THRU ROCK SILL AT END (TYP)

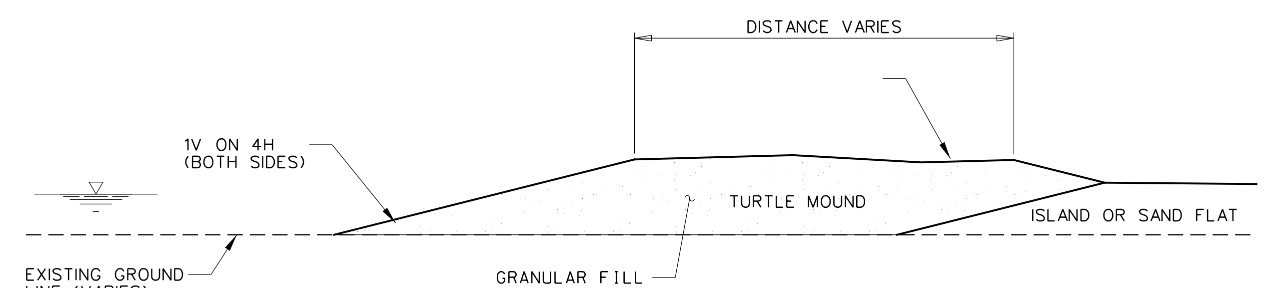
NOTES:
1. PLACE 6 INCHES OF CHINKING STONE ON UPSTREAM (UNPROTECTED) SLOPE OF ROCK SILL.



NOTES:

SECTION
THRU SAND FLAT & MUD FLAT

0 10' 20'



SECTION
TYPICAL TURTLE MOUND

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CONTRACT NO.:
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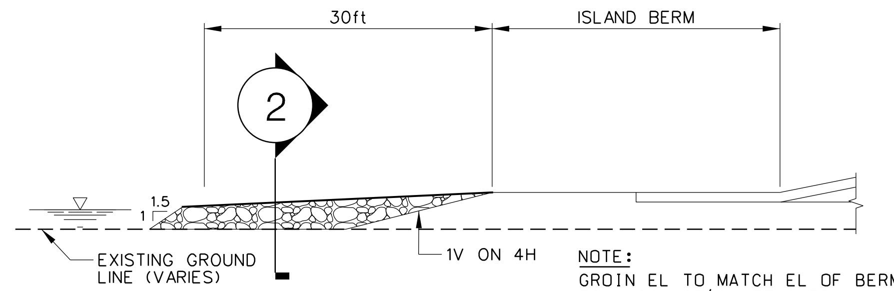
FILE NUMBER:
SIZE: D
FILE NAME:

HABITAT REHABILITATION AND ENHANCEMENT
MISSISSIPPI RIVER
ISLAND DESIGN MANUAL STANDARD DETAILS

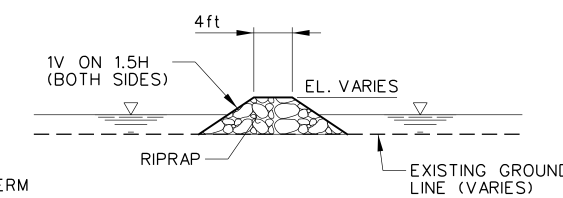
ROCK MOUND, ROCK SILL, MUD/SAND
FLATS & TURTLE NESTING MOUND

SHEET IDENTIFICATION
PLATE 4



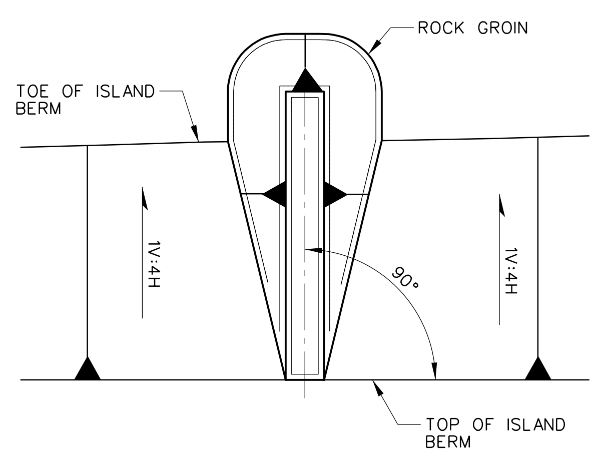
ELEVATION

TYPICAL ROCK GROIN



2 SECTION

TYPICAL ROCK GROIN/VANE



PLAN

TYPICAL ROCK GROIN

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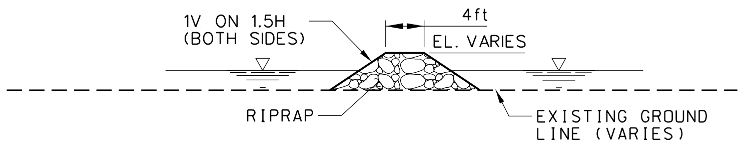
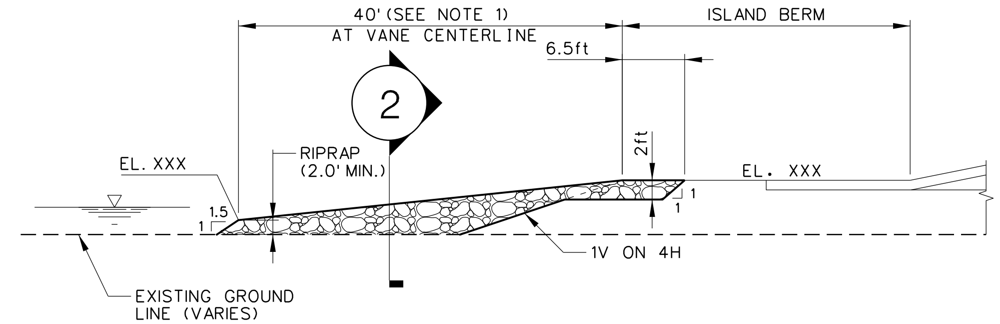
HABITAT REHABILITATION AND ENHANCEMENT
MISSISSIPPI RIVER
ISLAND DESIGN MANUAL STANDARD DETAILS

ROCK GROINS

SHEET IDENTIFICATION
PLATE 5

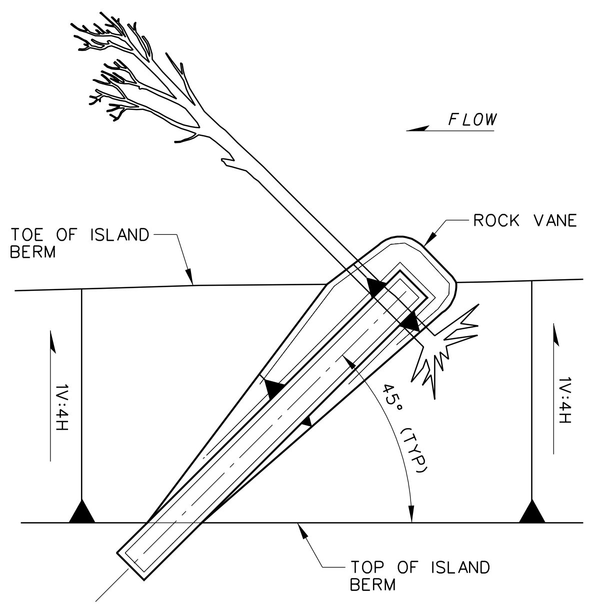


2 SECTION
TYPICAL ROCK VANE
0 10' 20'

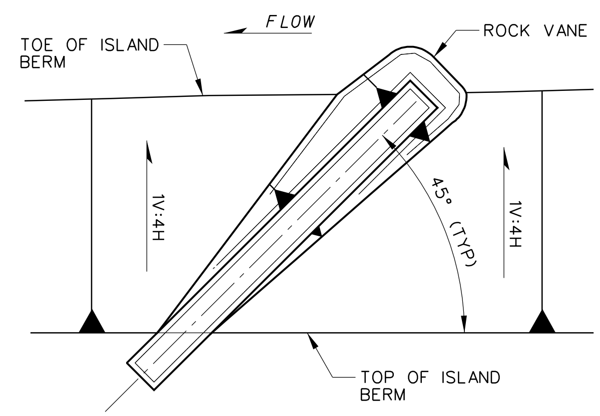


NOTE:
1. DISTANCE VARIES FOR J-HOOK VANES.

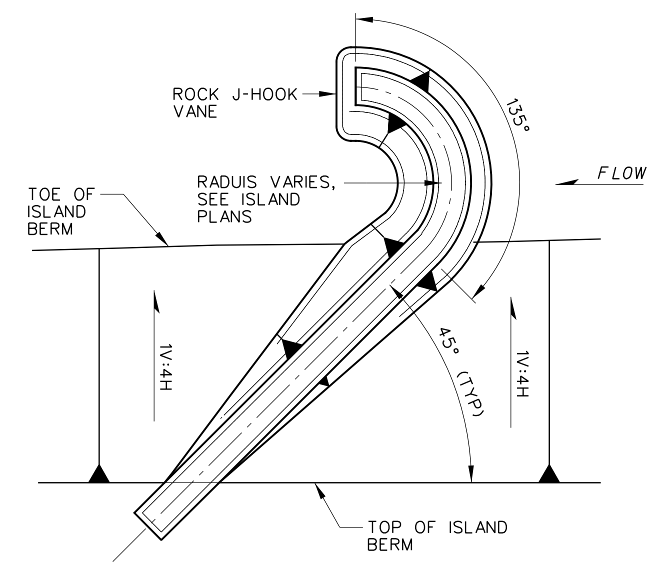
PROFILE
TYPICAL ROCK VANE
0 10' 20'



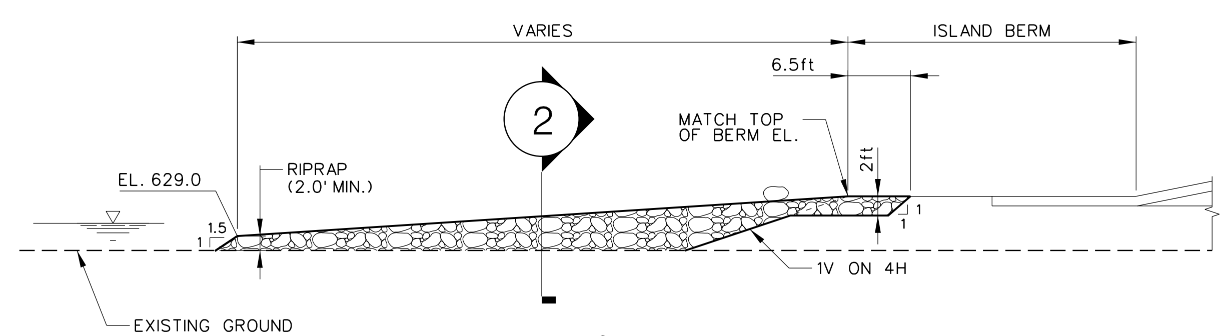
PLAN
TYPICAL ROCK VANE
0 10' 20'



PLAN
TYPICAL ROCK VANE
0 10' 20'



PLAN
TYPICAL ROCK J-HOOK VANE
0 10' 20'



PROFILE
TYPICAL ROCK J-HOOK VANE
0 10' 20'

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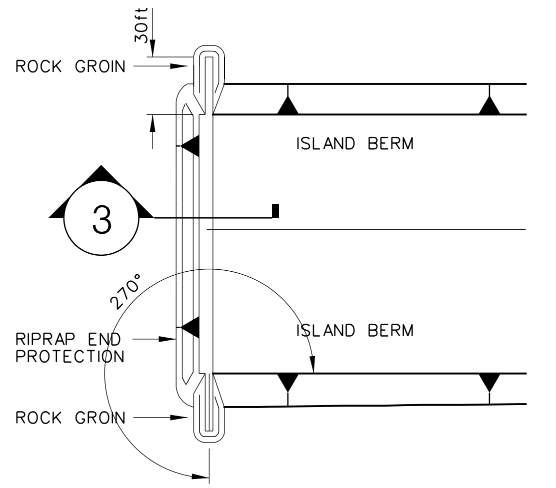
MISSISSIPPI RIVER
ISLAND DESIGN MANUAL STANDARD DETAILS

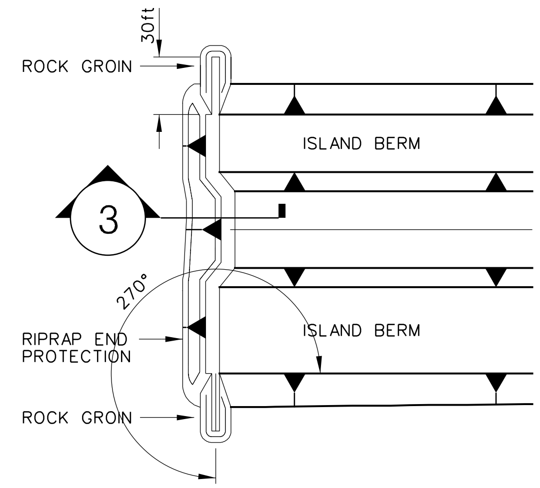
ROCK VANES
J-HOOK AND STANDARD

SHEET
IDENTIFICATION
PLATE 6



PLAN

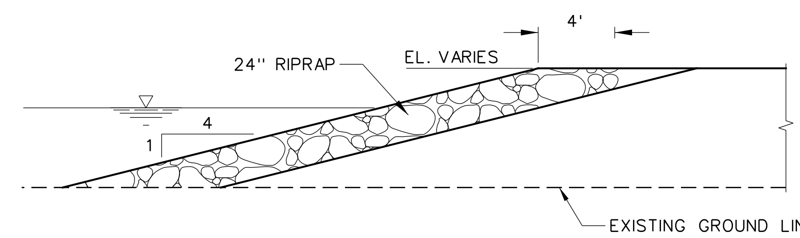
RIPRAP END PROTECTION
TYPE B ISLAND



PLAN

RIPRAP END PROTECTION
TYPE A ISLAND

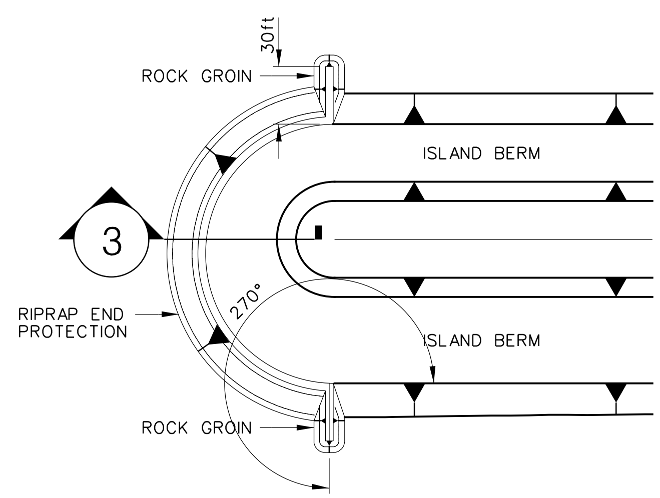
0 25' 50' 100'



3 SECTION

ISLAND RIPRAP END/BANK PROTECTION

0 25' 50' 100'



PLAN

RIPRAP END PROTECTION - ROUND

0 25' 50' 100'

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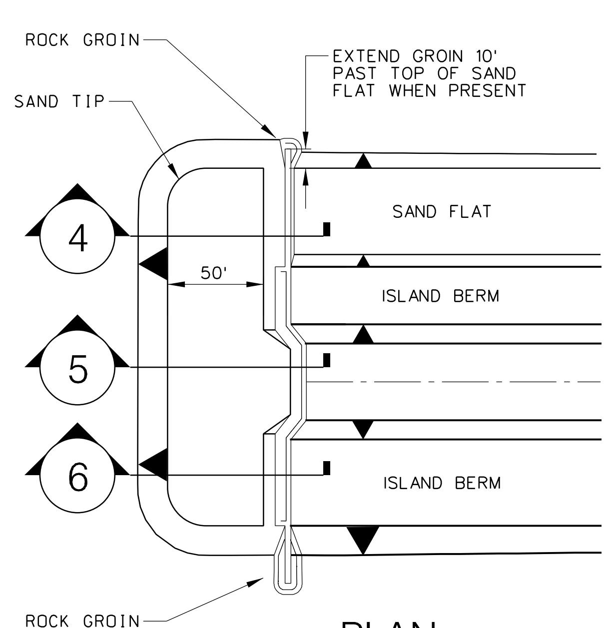
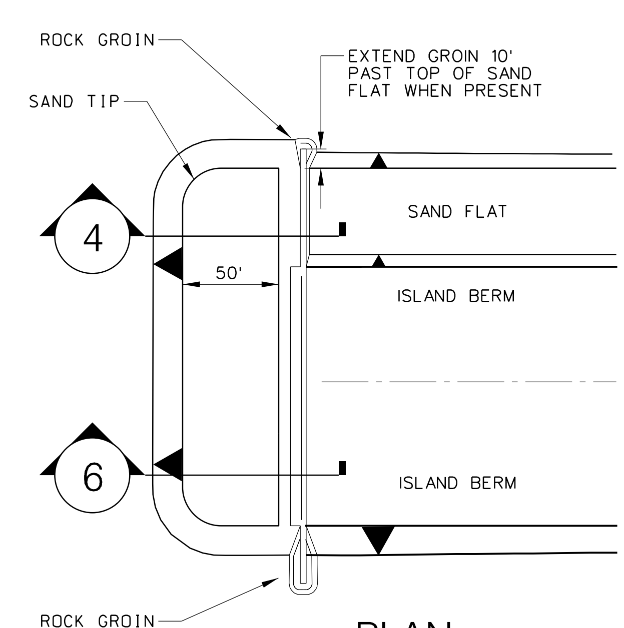
HABITAT REHABILITATION AND ENHANCEMENT
MISSISSIPPI RIVER
ISLAND DESIGN MANUAL STANDARD DETAILS

ISLAND END PROTECTION
PLAN AND SECTION

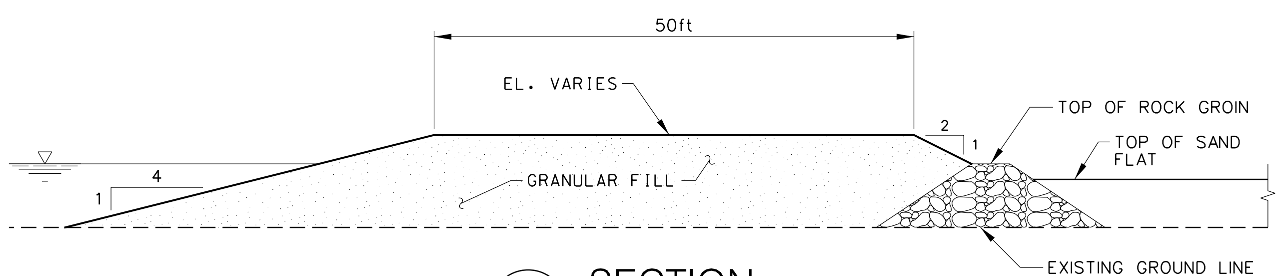
SHEET IDENTIFICATION
PLATE 7



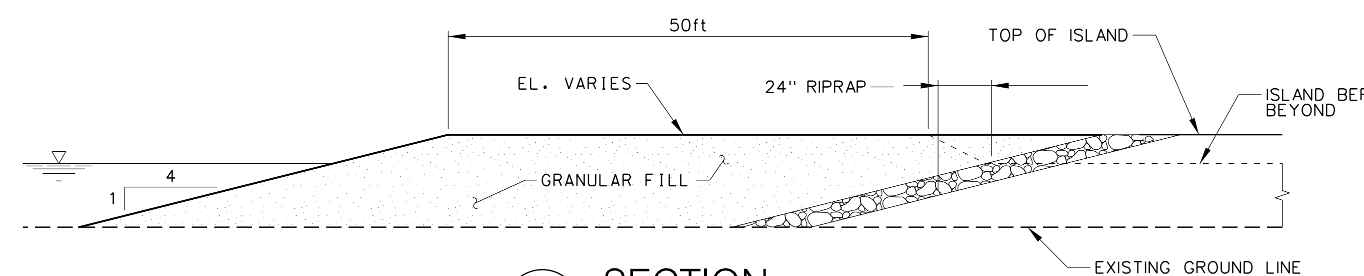
PLAN
RIPRAP END PROTECTION WITH SAND TIP TYPE A ISLAND



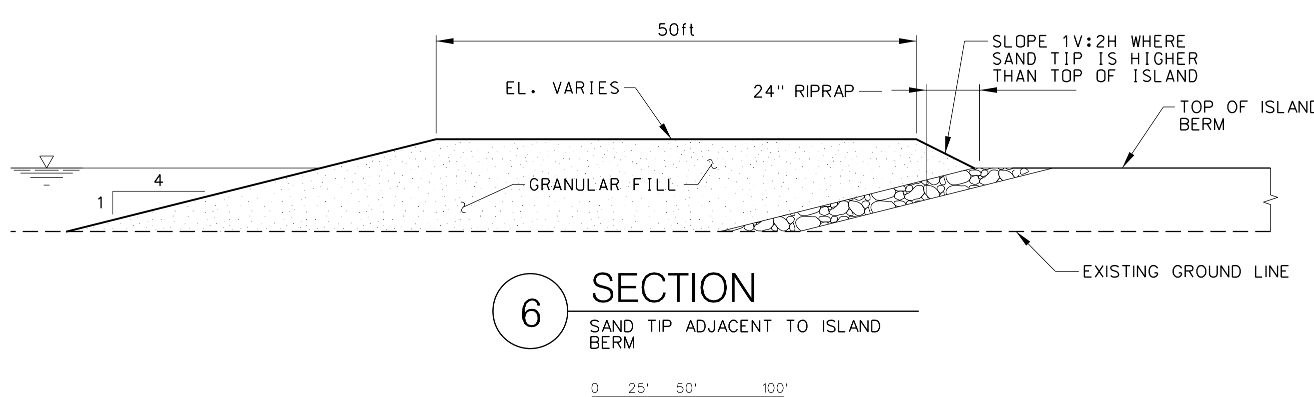
PLAN
RIPRAP END PROTECTION WITH SAND TIP TYPE B ISLAND



4 SECTION
SAND TIP ALONG ROCK GROIN



5 SECTION
SAND TIP AT TOP OF ISLAND



6 SECTION
SAND TIP ADJACENT TO ISLAND BERM

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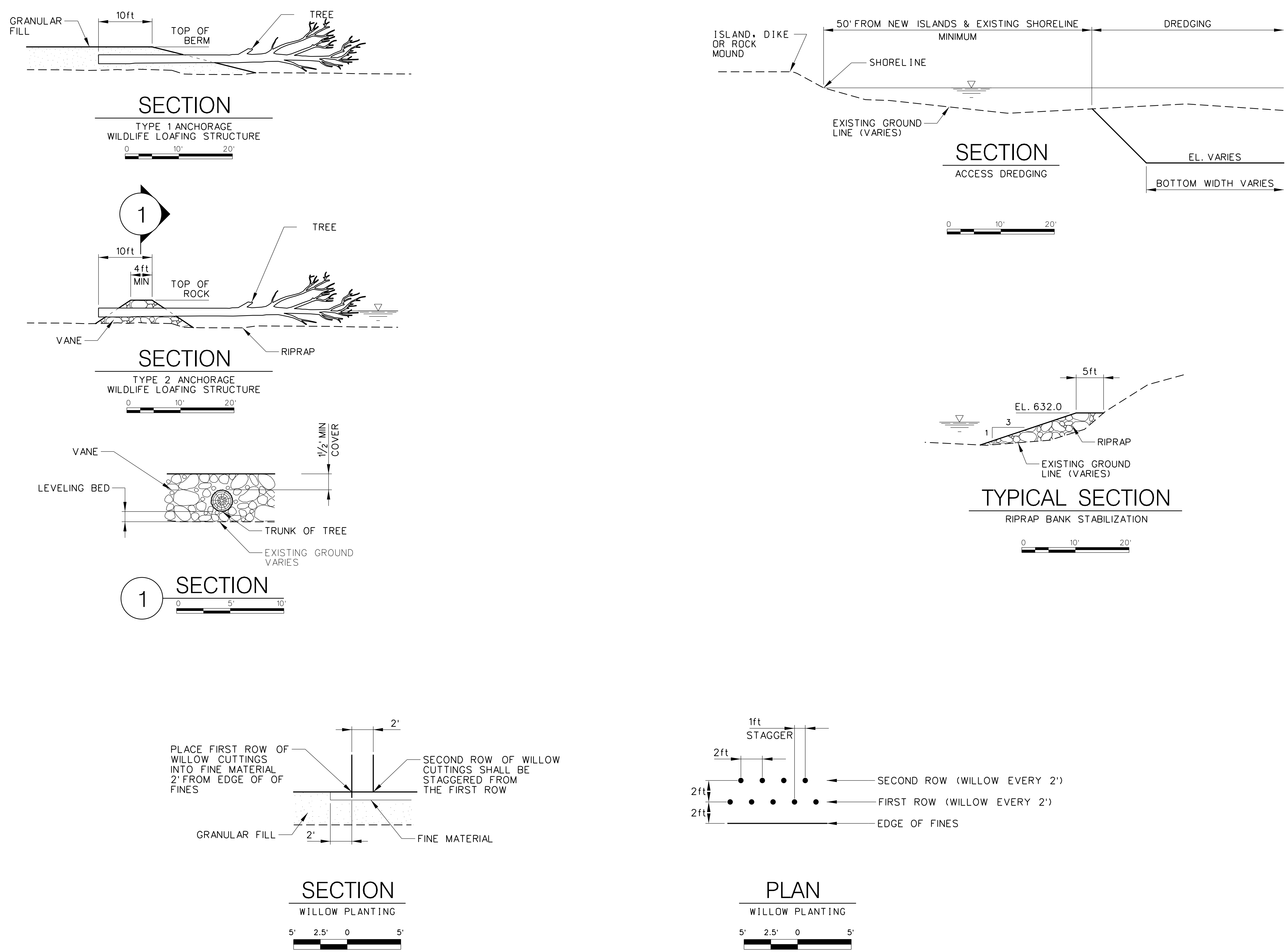
HABITAT REHABILITATION AND ENHANCEMENT
MISSISSIPPI RIVER
ISLAND DESIGN MANUAL STANDARD DETAILS

ISLAND SAND TIP

SHEET IDENTIFICATION
PLATE 8



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PLOT SCALE: 1"=10'	PLOT DATE: No	FILE NUMBER:	
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HABITAT REHABILITATION AND ENHANCEMENT
MISSISSIPPI RIVER
ISLAND DESIGN MANUAL STANDARD DETAILS

WILDLIFE LOAFING STRUCTURES AND MISCELLANEOUS DETAILS

SHEET IDENTIFICATION
PLATE 9

UPPER MISSISSIPPI RIVER RESTORATION
ENVIRONMENTAL MANAGEMENT PROGRAM
ENVIRONMENTAL DESIGN HANDBOOK

APPENDIX 9-F

CONSTRUCTION LESSONS LEARNED

APPENDIX 9-F

CONSTRUCTION LESSONS LEARNED

FIGURES

PHOTOGRAPHS

APPENDIX 9-F

CONSTRUCTION LESSONS LEARNED

A. FEATURE TYPE OR CONSTRUCTION ACTIVITY

1. Access Channels

a. Resource Problem. Access channels and dredging need to be minimized to not impact existing habitat which includes submerged vegetation and mussels.

b. Design Methodology. Design access routes to use deeper water areas to the extent possible. Verify that bathymetry is current. Include access pads where necessary to improve access and reduce habitat damage.

c. Lessons Learned

i. The depth of access channels should be verified before solicitation.

ii. Access dredging should be included in plan submitted by Contractor subject to review and acceptance by the Government before work commences

iii. The Contractor shall perform surveys prior to access dredging, and after access dredging. Surveys shall be complete and in enough detail to accurately verify pre- and post-access dredging areas are per contract

d. References

a. WI Chapter 30/WCC
b. USFWS Conditional Use Permit
c. EMP Design Manual

e. Case Studies

i. Case Study 1. Pool 8, Phase III Stage 3A. Raft Channel – access dredging was required

ii. Case Study 2. Capoli Slough Stage1. Based on bathymetry, access dredging will be necessary. Allowable locations are shown on the drawings. Bottom elevation of all access dredging is 614.1. The access point and footprint can't be changed within the first 300 feet off the main channel. Beyond 300 feet, the final alignment of access dredge cuts could be adjusted to take advantage of deeper water but avoid sensitive areas. Invite the Wisconsin DNR and USFWS to review alignment. Alternative access points will require mussel surveys and potential mussel relocations. The Contractor would be allowed to place access material in the emergent wetlands identified or as random fill in the island cross sections.

2. Access Pads. Most EMP projects with island construction have limited site access, and restrictions minimizing the use of access dredging. After suggestions from Contractors, recent contract plans have included an option for access pads adjacent to islands. These pads, with a maximum footprint of 100 feet x 250 feet, are constructed with granular material and allow both a staging area and an access point often with deeper water. The access pads in most cases are required to be removed after construction is complete. A confirmation survey of the removal, similar to the one shown in figure 9-F-1, is required to insure the removal is completed to the original grade.

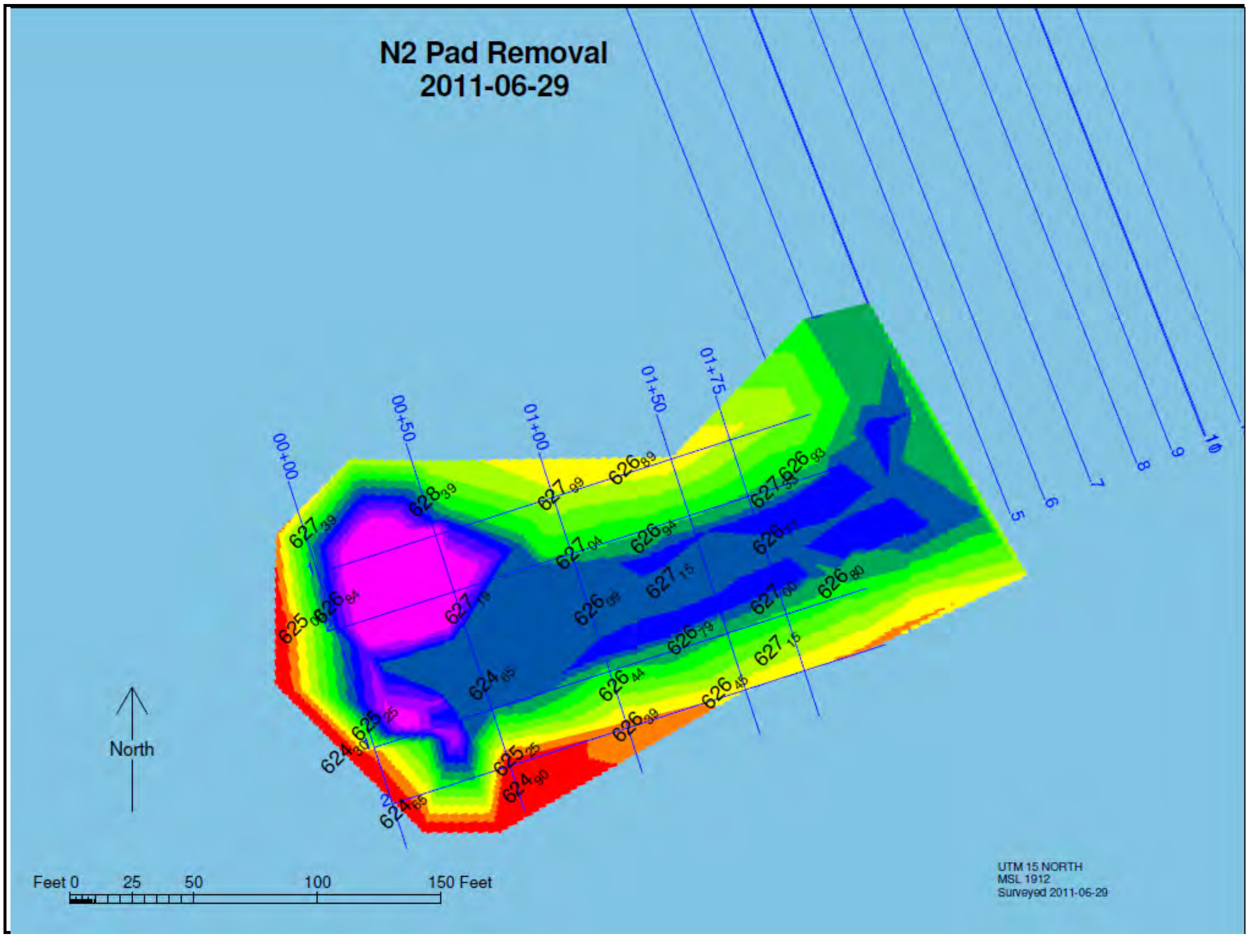

Figure 9-F-1. Access Pad – Post-Removal Survey (Typical)

3. Borrow Areas

a. Resource Problem. Fill materials should be obtained from the closest source possible that meets both the design requirements and/or provides a beneficial use.

b. Design Methodology

i. Borrow Areas. These areas should be tested before the solicitation is advertized to insure the available material meets the contract specifications.

ii. Granular. The contract documents should define acceptable borrow areas. Sources may be from the main channel, nearby dredge material placement sites, or backwater areas near the project site with suitable material.

iii. Fine Material. Fine materials are often available at the project site from access dredging or nearby designated fine borrow areas. In recent Pool 8 projects, the mandatory fine borrow were locations that provided improved habitat and or navigation access after dredging was completed.

iv. Random Material. Random material can be obtained from access dredging or granular borrow locations and placed in islands or in emergent wetlands.

Alternate borrow sites should be evaluated on a case-by-case basis for approval and would likely require mussel surveys to evaluate potential impacts on mussels. If the Contractor wishes to suggest alternate borrow areas, sufficient time, preferably 60 days, should be provided to allow comprehensive review by the Corps and permitting agencies.

c. Lessons Learned. Before work commences, the Contractor should perform "pre-surveys" of all fill and borrow areas. It is recommended that the Contractor place levee templates to create survey cross sections and run quantity calculations to verify project qty requirements. This helps in determining if there are significant differences between the plans and actual conditions. The pre-survey also includes staking of exclusion zones, pipeline routes, etc. Pre-survey should include the following project features:

- all island locations
- granular and fine borrow areas
- emergent wetlands including optional wetlands, rocksills, borrow sources (interior). It is recommended that channel cuts also be provided.
- access channels
- limits of exclusion zone –need to be staked
- pipeline routes – need to be staked

After each feature of work is completed, a post-dredge survey will be performed to determine payable quantities and consistency with applicable pre-dredge survey. Examples of typical post-dredge surveys for a granular and fines are shown in figures 9-F-2 and 9-F-3.

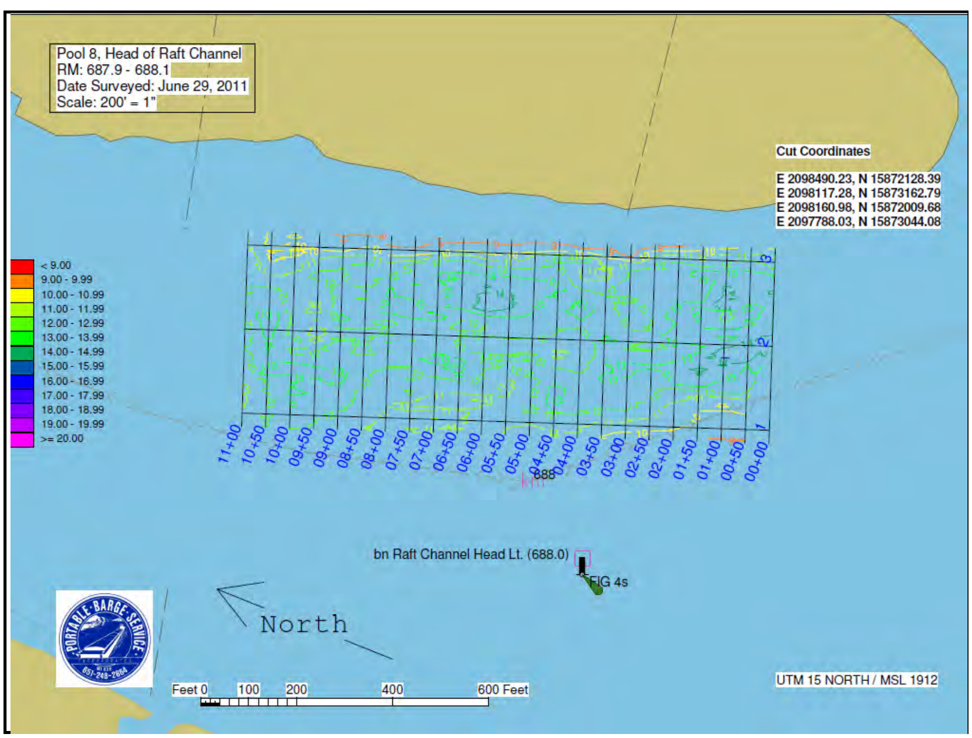

Figure 9-F-2. Main Channel Granular Borrow – Post-Dredge Survey (Typical)

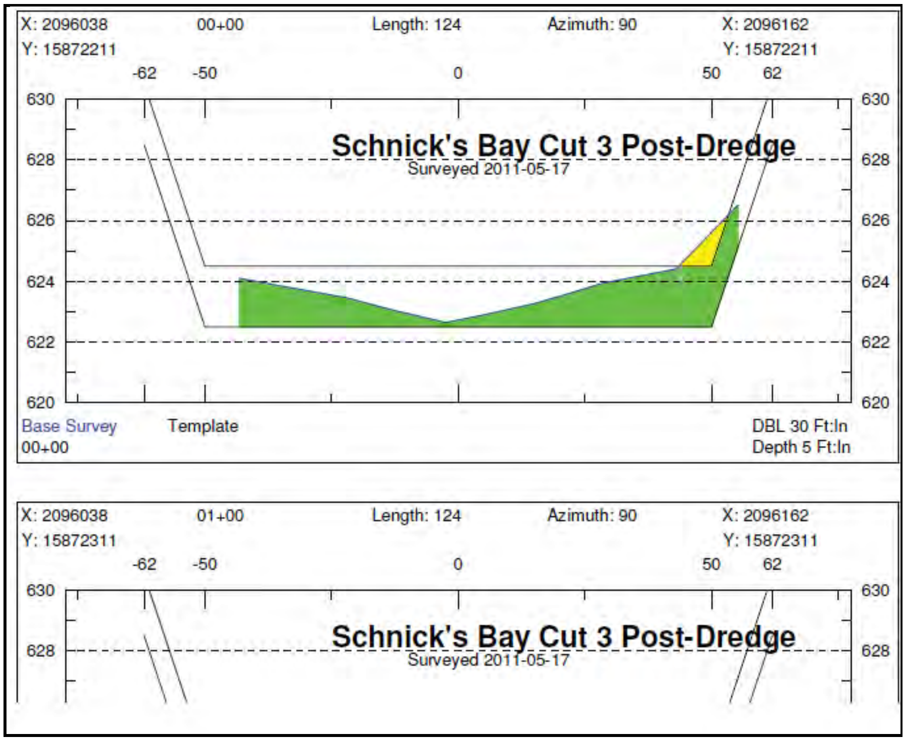

Figure 9-F-3. Fine Borrow Area – Post-Dredge Survey (Typical)

B. EMERGENT WETLANDS

1. Background. Emergent wetlands are project features on EMP island projects. Initially they started out as "mudflats" with minimal habitat benefits where excess random material could be stored or placed. Through trial and error with several projects, it was found that these areas could have significant habitat benefits if they were constructed properly; they have come to be known as "emergent wetlands."

Proper construction means the materials placed into the emergent wetlands should not be solely granular materials, but a mixture of materials if possible. The average elevation of these wetlands should range from 1 foot below LCP to 1 foot of above LCP. This allows portions of the wetland to be submerged and encourages a more diverse habitat. For the Pool 8 Phase 3 Stage 3A contract for example the LCP was 619.5 and the emergent wetlands elevations shall were constructed from 618.5 to 620.5, with a mean elevation of 619.5. In addition, the emergent wetlands should slope toward the sand berms and away from the islands.

2. Containment Berms. The length of the containment berms must be sufficient to contain the material placed within the emergent wetland. The plans describe the berm cross section. If some additional granular material needs to be placed by the Contractor, the width of the berms can be increased, but all any surplus granular material should be pushed into the emergent wetland and none may be pushed to the outside.

3. Material Placement. During hydraulic placement, excess water is let out of the wetland through an outlet weir. The water must be tested to insure the water quality does not exceed permit requirements. After filling emergent wetland and random and fine materials have settled out, the Contractor should score (or breach) the berm at several locations and push the excess material into the emergent wetland. The breaching allows water levels to equalize on either side of the berm.

The following photographs and figure show construction of emergent wetlands on two recent EMP Projects in Pool 8. Photograph 9-F-1 shows the C4 wetland after the berm has been completed and the Contractor began dredging and pumping fine/random material into the wetland. Photograph 9-F-2 shows an emergent wetland on Island N7 2 years after construction was completed. Figure 9-F-4 shows the work plan layout for Stage 3A contract including the pipeline route from the fines borrow source to the placement in the Island C4 emergent wetland.

Photograph 9-F-1. C4 Mudflat – Stage 3A (Emergent Wetland Under Construction)

Photograph 9-F-2. Emergent Wetland (Typical), Pool 8, Stage 2B, Island N7 – 2 Years After Completion

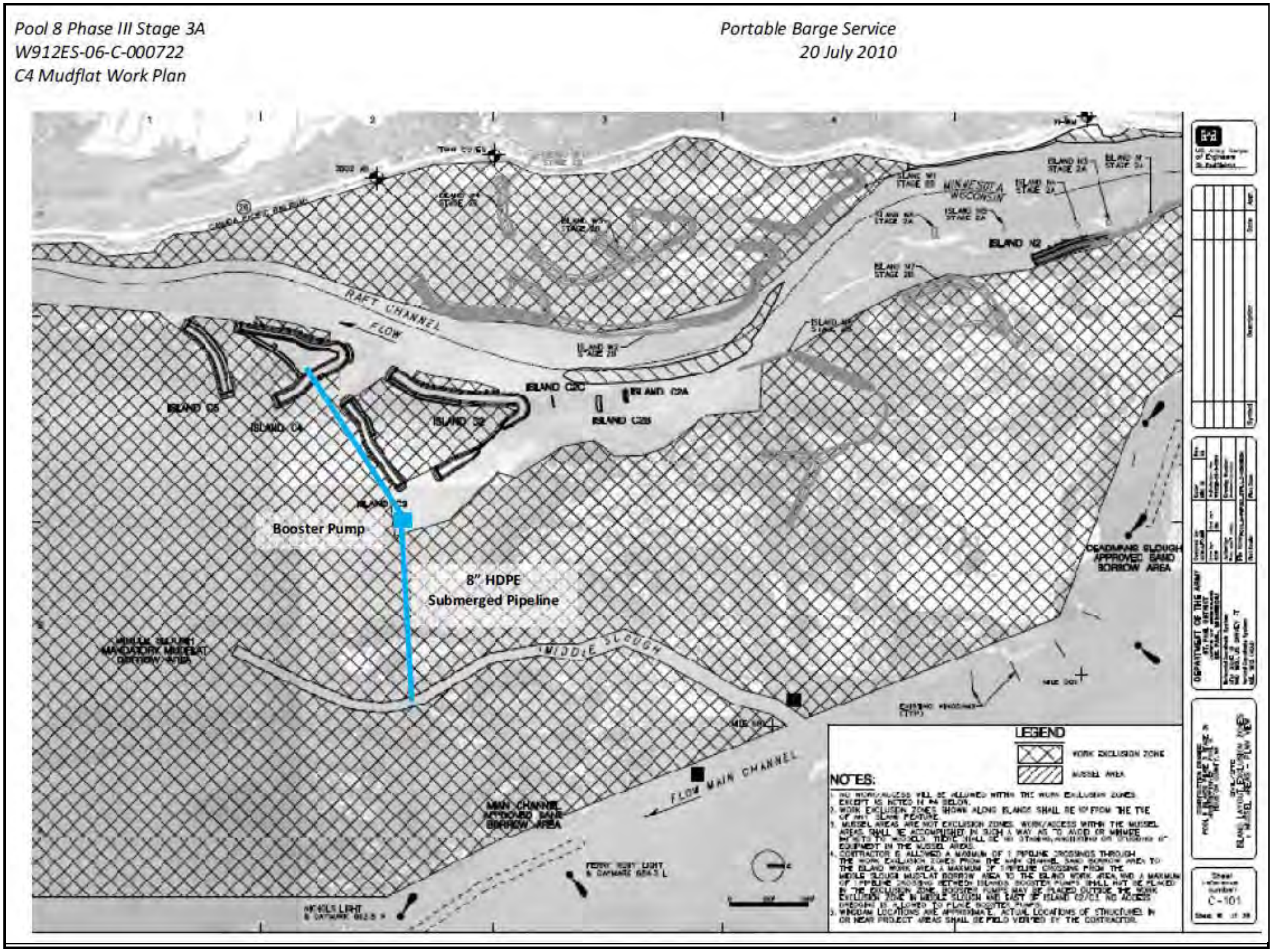

Figure 9-F-4 Emergent Wetland Work Plan – Stage 3A

C. ROCK

Placement of rock groins, vanes and slope protection needs to occur as soon as possible after sand placement to limit erosion from waves and wind. Protection may be required during island construction or immediately after granular placement depending on severity of wind and flow conditions. For construction details, see Specification Section 35 31 19.00 13, STONE PROTECTION (RIPRAP), in the contract document for construction details.

D. EXCAVATION/ACCESS LIMITS

- **No dredging/access in the work exclusion zones.** Limited pipeline crossings through the exclusion zone are allowed per notes on the contract drawings. The Contractor should anchor the pipeline to insure that does not move and cause unnecessary. Details will be provided by Contractor pre-work plans. See example of a tugger barge in photograph 9-F-3.
- **No dredging within 50-feet from new/existing islands and shorelines.**
- In accordance with permit conditions, any proposed access dredging ***beyond those defined by the permit*** needs to be coordinated/reviewed by the permitting agencies to include Wisconsin DNR and the USFWS prior to approval.
- The Contractor should **mark the exclusion zone(s)** in accordance with approved work plan and contract requirements.
- The Contractor is to use **access channels** to get to and from the work areas. These access channels should also be clearly marked.

Photograph 9-F-3. Tugger Barge (used to hold pipeline in place)

E. PUBLIC ACCESS

The Contractor is responsible for insuring the safety of their work areas. Effective communication with the public concerning the project helps to control site access during working hours. Photograph 9-F-4 shows an example of Notice to the Public Pool 8 Phase III - Stage 3B. The USFWS will provide a similar brochure for the Capoli Project.

Photograph 9-F-4. Notice to the Public at Pool 8 Phase III - Stage 3B Kiosk

F. PERMITS

EMP contract work is to be performed in accordance with the following permits:

- Wisconsin Chapter 30 Permit & Wisconsin Water Quality Certification or applicable agency in state with the jurisdiction.
- Special Use Permits - USFWS provides a permit for each project.
- USFWS Bald Eagle Permit – This a new permit used for the first time under Capoli Stage 2 with USFWS that allows for some less restrictive requirements for work in proximity to eagle nests.

G. WATER QUALITY STANDARDS

Water Quality Standards will be issued by the Wisconsin DNR or respective state agency. In MVP specs see Chapter 30 WCC permit attached to Section 01 57 20.00 13.

H. PROJECT COORDINATION

In MVP, all projects are located within the Upper Mississippi River National Wildlife and Fish Refuge; therefore, involvement by the USFWS is required. That agency, as well as the Iowa and Wisconsin DNRs (or applicable state agencies), should be coordinated with regarding invitations to meetings, review of substantial project modifications, plantings, willow locations, placement of wildlife loafing structures, etc.

I. PLANTINGS/TOPSOIL

- **Low Islands (<4 ft below LCP).** Recommend minimum 9" of fine material
- **Medium to High Islands (>4ft of above LCP).** Recommend minimum of 12" of fine material
- **Seeding.** Should extend from fine material to fine material
- **Trees.** Recommend willows be planted along island perimeter for erosion protection. Depending on island height and desired habitat, additional trees can be planted later by others.
- **Planting and Seeding Dates.** Experience has shown that willows not planted by June 15th rarely survive. If the moisture and soil conditions are favorable, seeding can be done in all but the hottest part of the summer season. (June 30 – August 15)
- **In MVP.** USFWS has provided a source for willows on all recent contracts. Location Map and restrictions are included within the contract.

J. STAGING AREA

Staging areas need to be identified during the planning and design phase to allow the Contractor marine access and loading of rock materials. Depending on the proximity of these public areas, the Contractor may seek private staging or loading areas closer to the project

K. ISLANDS

- **Dimensions.** For economic constructability with mechanical placement, an island should be at least 35 feet wide. For hydraulic placement, an island usually needs to be at least 100 feet wide.
- **Temporary Haul Roads.** Temporary haul roads (photograph 9-F-5) have been used to improve construction access in locations where limited access dredging is allowed.

Photograph 9-F-5. Construction of a Permit Approved Access Road, Stage 3A Project

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