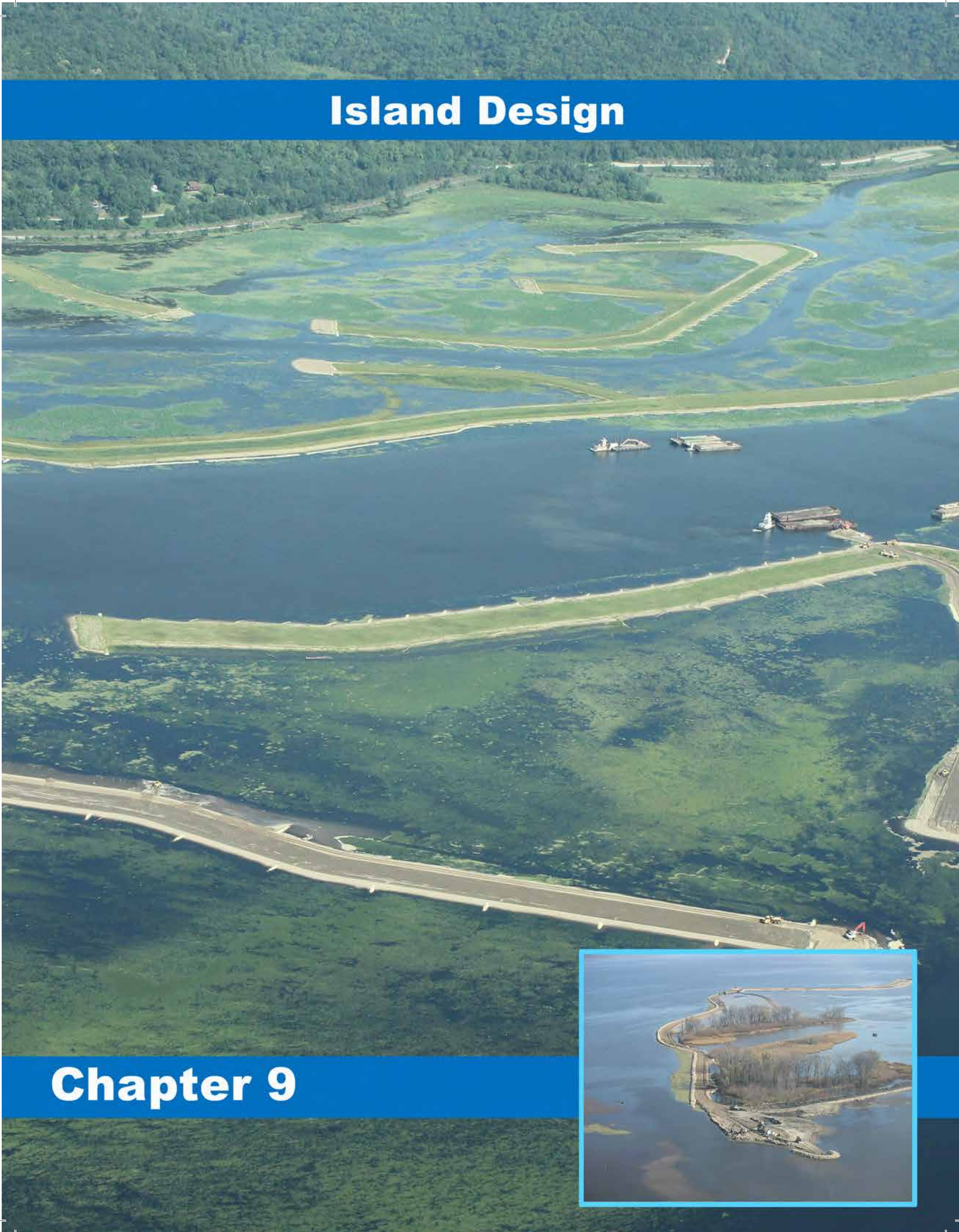
Island Design



Chapter 9

UPPER MISSISSIPPI RIVER RESTORATION ENVIRONMENTAL MANAGEMENT PROGRAM ENVIRONMENTAL DESIGN HANDBOOK

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.

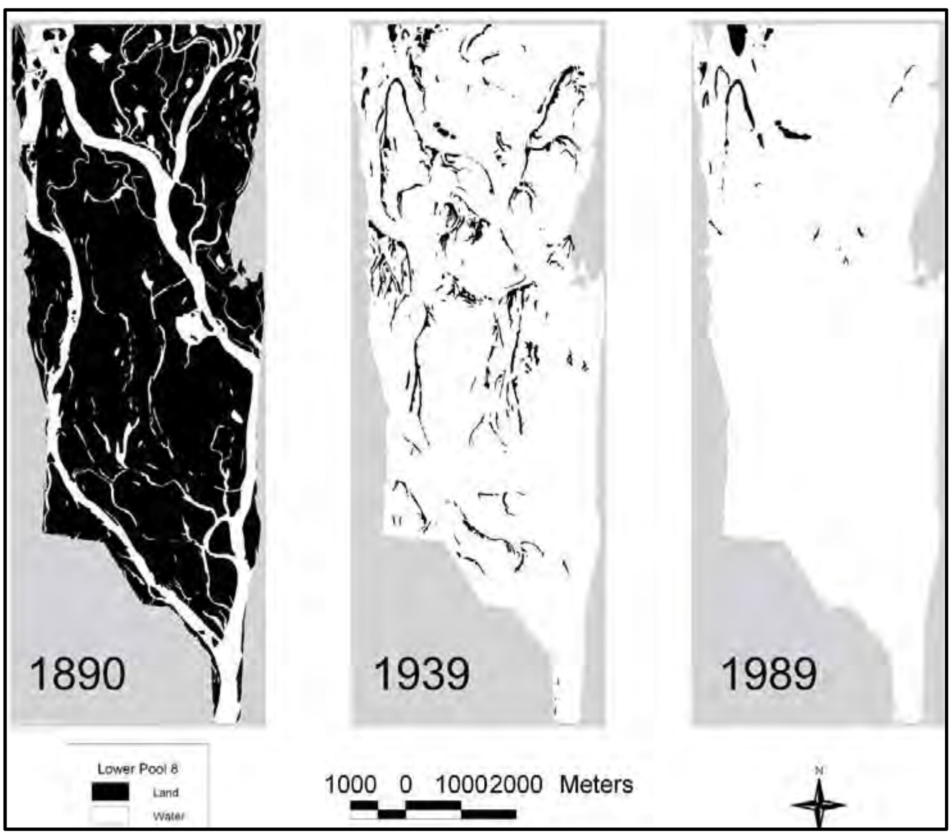


Figure 9-1. Land-Water Conditions In Lower Pool 8

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).

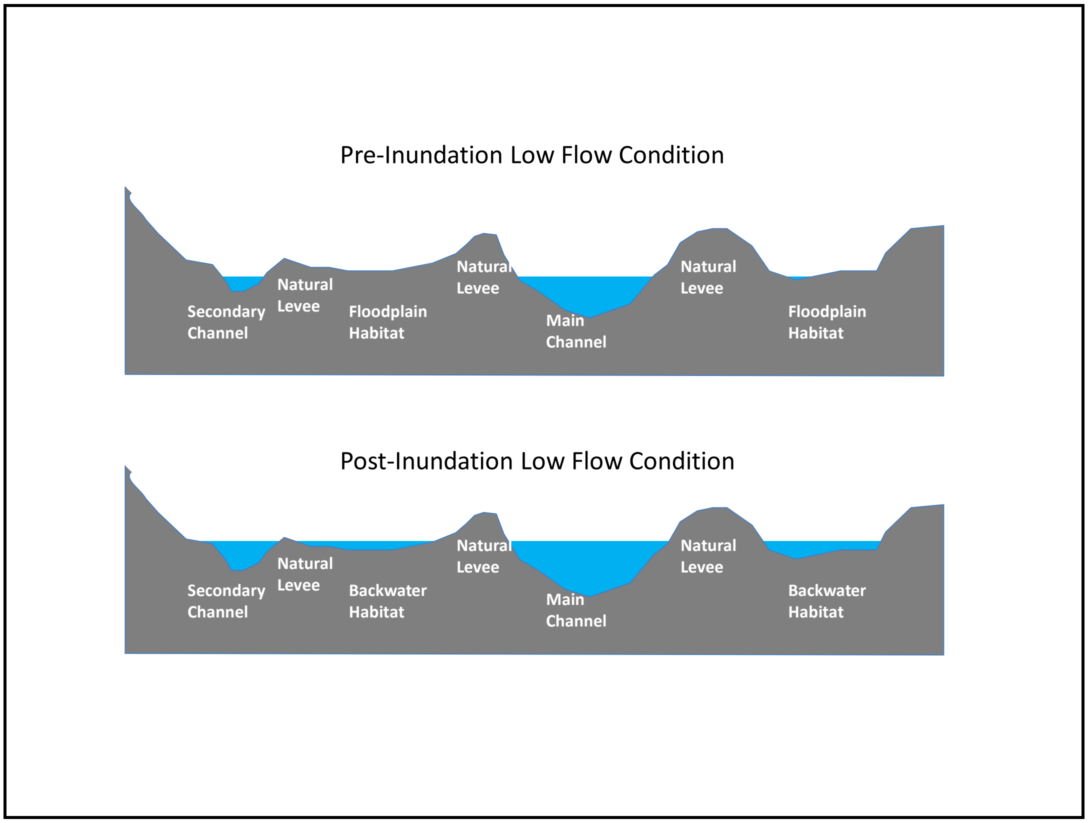


Figure 9-2. Changes Caused by Raised Water Surface Elevation in the Lower Reach of Navigation Pools

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:

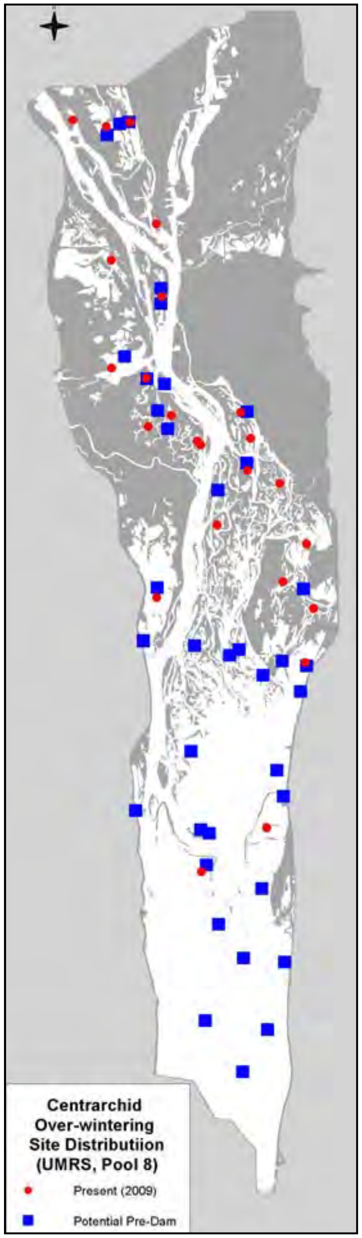
> *The UMRS refuge generally supports 60 to 75 percent (82 percent in 2005) of the Canvasbacks counted in the eastern U.S. during annual Coordinated Canvasback surveys (figure 9, pg 238, UMRS Refuge CCP, 2006). Current observations and survey data clearly show that ducks, swans and geese are not evenly 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.



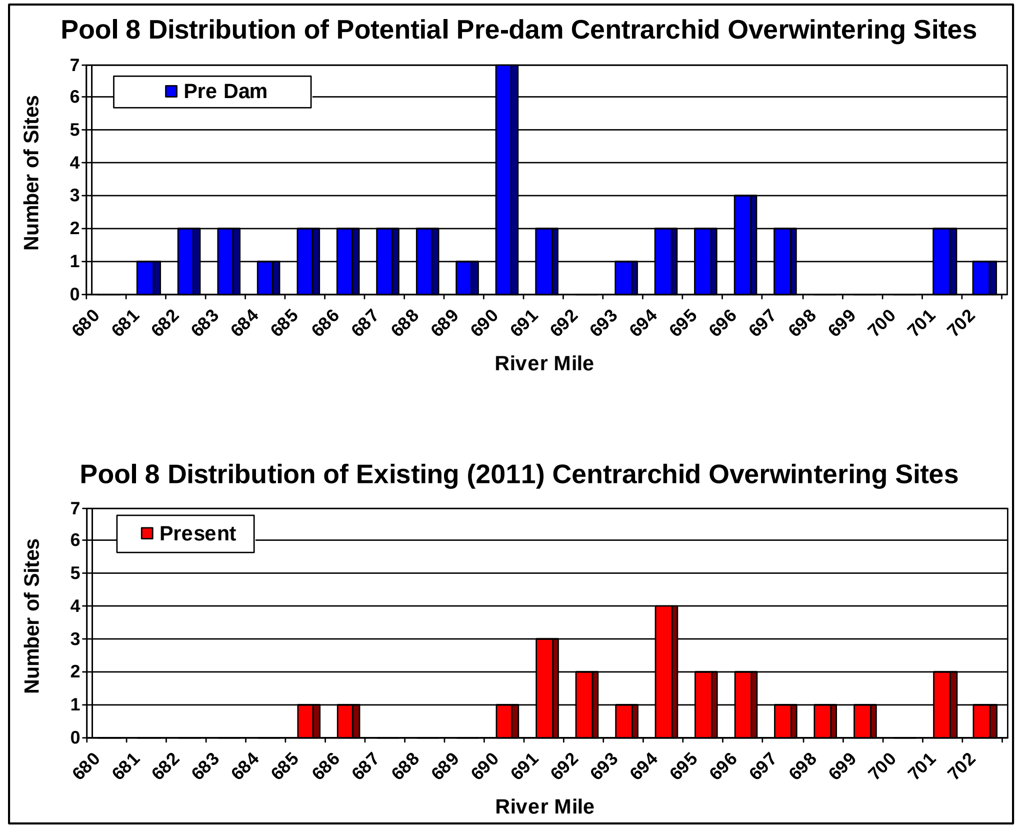
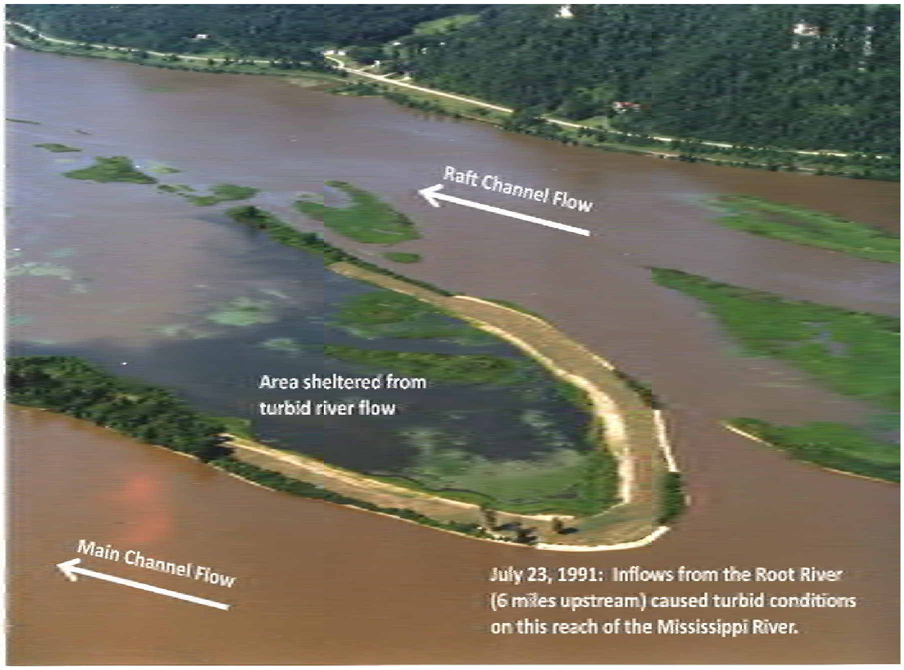


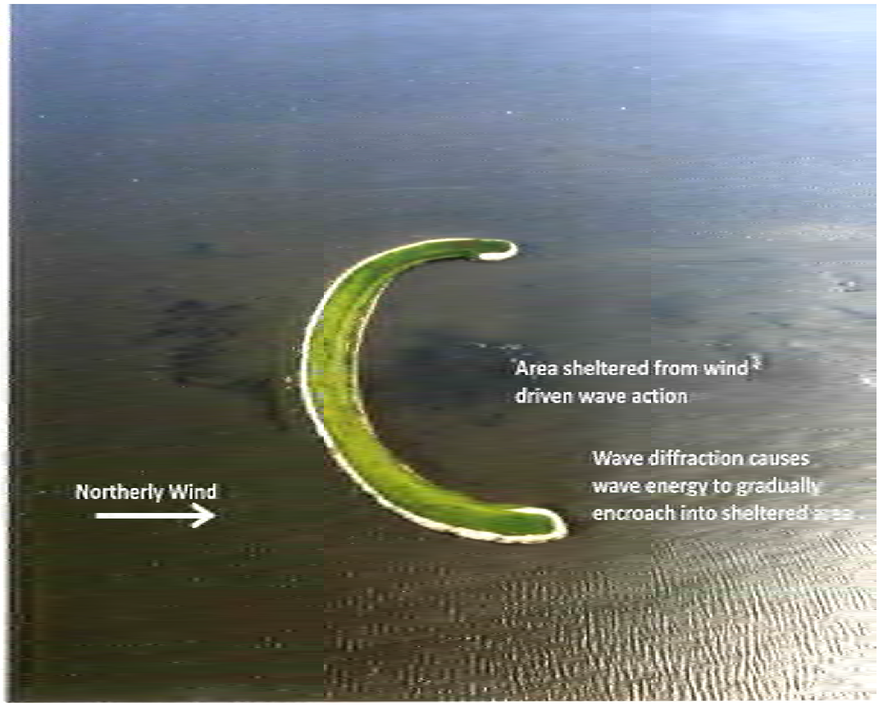
Figure 9-3. Potential Pre-Dam Distribution of Centrarchid Overwintering Habitat and 2011 Distribution of Centrarchid Overwintering Sites In Upper Mississippi River, Pool 8 (Janvrin, Wisconsin DNR, unpublished)

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.

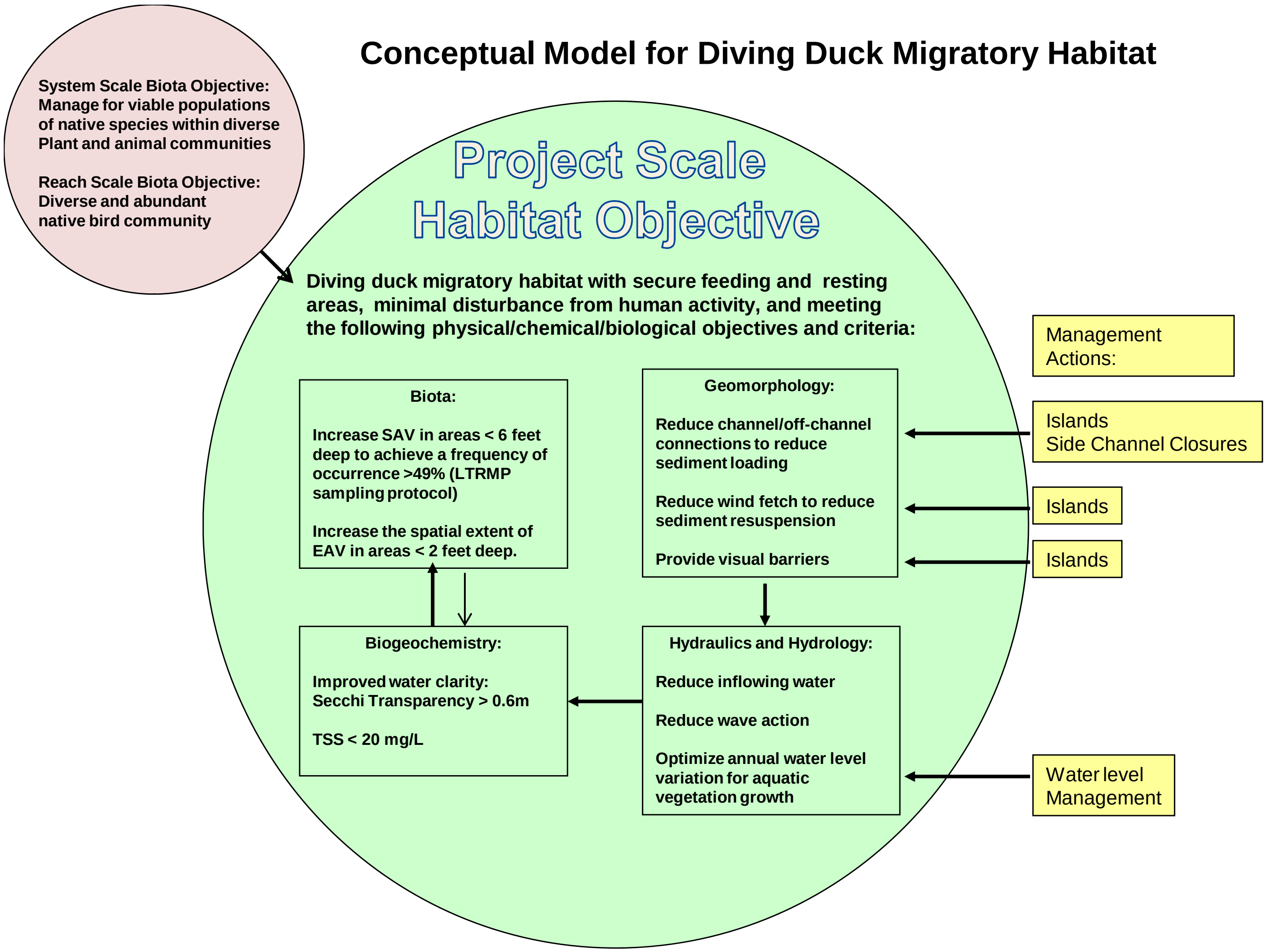


Figure 9-4. Conceptual Model for Diving Duck Migratory Habitat Illustrating the Relationship Among Objectives, Performance Criteria, and Management Actions

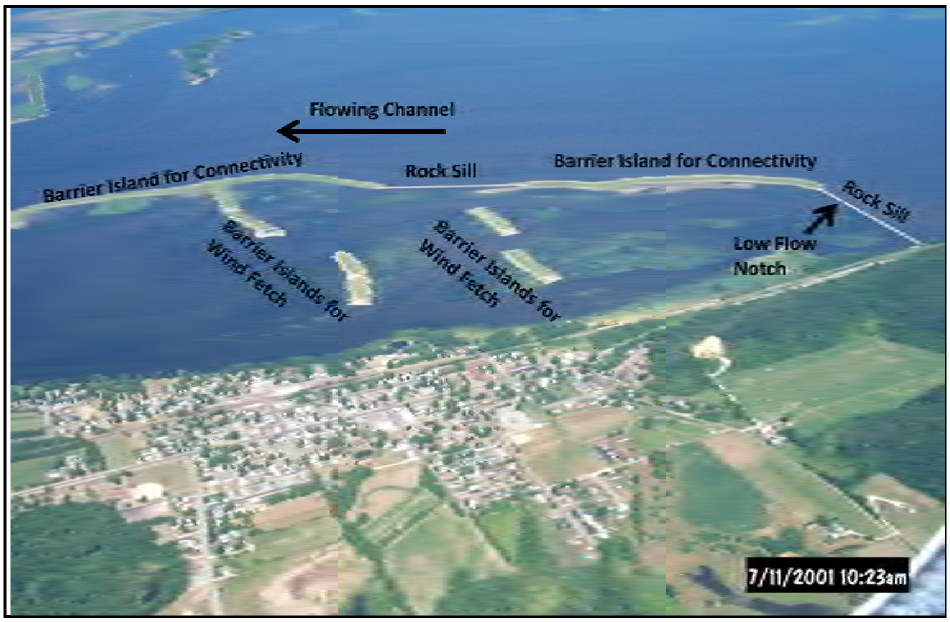
B. BARRIER ISLAND CONSTRUCTION

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.

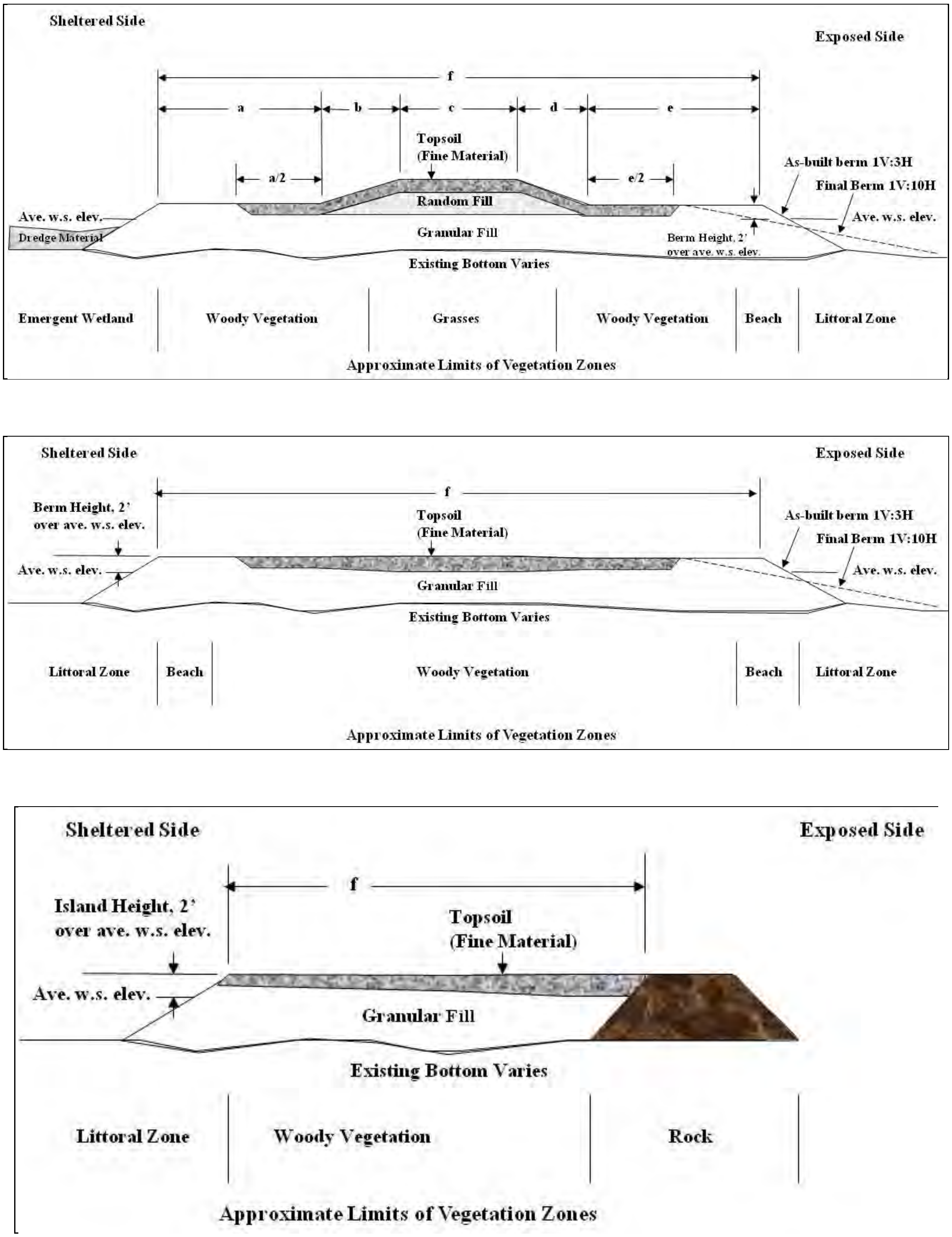


Figure 9-5. Island Cross Sections Typically Used for Island Construction

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

Design Discipline	Design Criteria
Geomorphology	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*
Engineering	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)* 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)* 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*
Constructability	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* 5.f Use a maximum of 8-inches of fine sediment when disking with standard farm equipment. *Habitat Parameter 4 (App. 9-B)* 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* 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* 5.i Utilize sacrificial berm material for construction of temporary berms when placing topsoil hydraulically. *Lessons Learned 5.H.2* 5.j Minimize construction equipment travel over fine material to prevent soil compaction. *Lessons Learned 5.C.3*
Habitat	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)* Vegetation Type — Topsoil Thickness Shrubs , Trees — 12" or greater Grasses — 6" to 12" 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* 5.m Consider techniques to discourage grazing of new plants during the first few years after construction. *Lessons Learned 5.J.1* 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*

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.

<table>
<tr><th>Design Discipline</th><th>Design Criteria</th></tr>
<tr><td>Geomorphology</td><td>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</td></tr>
<tr><td>Engineering</td><td>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)</td></tr>
<tr><td>Constructability</td><td>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.</td></tr>
<tr><td>Habitat</td><td>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)</td></tr>
</table>

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

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PHYSICAL RIVER ATTRIBUTES:
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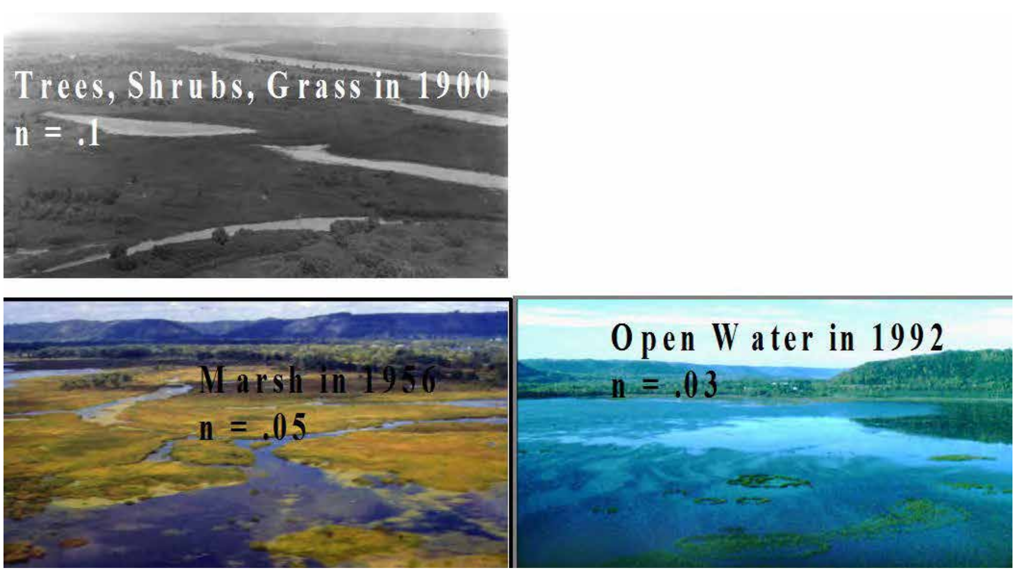
HYDRAULICS, SEDIMENT TRANSPORT, AND GEOMORPHOLOGY

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 (Δz_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 (Q_f/Q_t increased, 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

<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. 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.</td><td>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.

Water Surface Elevations for Low Flow and Bankfull Flow Conditions
at Lock and Dams 4 through 10.

<table>
<tr><th>Pool</th><th>Low Flow Water Surface
75% Exceedance</th><th>Bankfull Flow
1.5 yr Flood</th><th>Difference
(ft)</th></tr>
<tr><td>4</td><td>667.0</td><td>666.5</td><td>-.5</td></tr>
<tr><td>5</td><td>659.8</td><td>659.5</td><td>-.3</td></tr>
<tr><td>5A</td><td>650.8</td><td>650.8</td><td>0</td></tr>
<tr><td>6</td><td>645.4</td><td>644.5</td><td>-.9</td></tr>
<tr><td>7</td><td>639.0</td><td>639.0</td><td>0</td></tr>
<tr><td>8</td><td>630.7</td><td>630.0</td><td>-.7</td></tr>
<tr><td>9</td><td>619.5</td><td>620.0</td><td>.5</td></tr>
<tr><td>10</td><td>611.0</td><td>612.6</td><td>1.6</td></tr>
</table></td></tr>
<tr><td>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.</td><td>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.</td></tr>
</table>

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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.

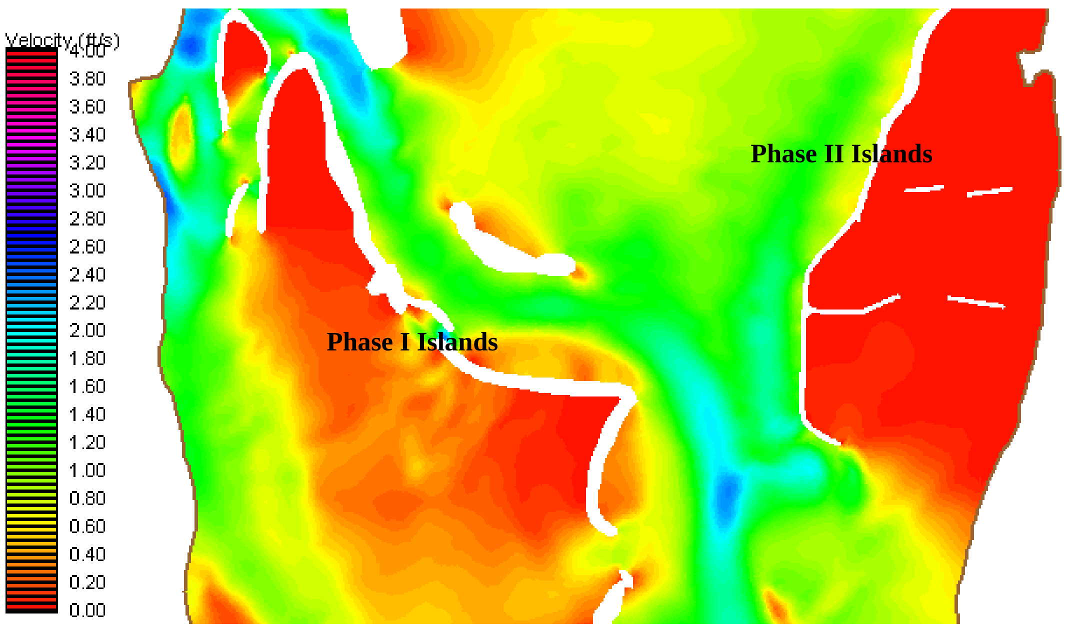

Figure 9-B-1. Current Velocity in the Pool 8, Phase I and II Areas Based on 2-Dimensional Modeling.

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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UPPER MISSISSIPPI RIVER RESTORATION
ENVIRONMENTAL MANAGEMENT PROGRAM
ENVIRONMENTAL DESIGN HANDBOOK

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.

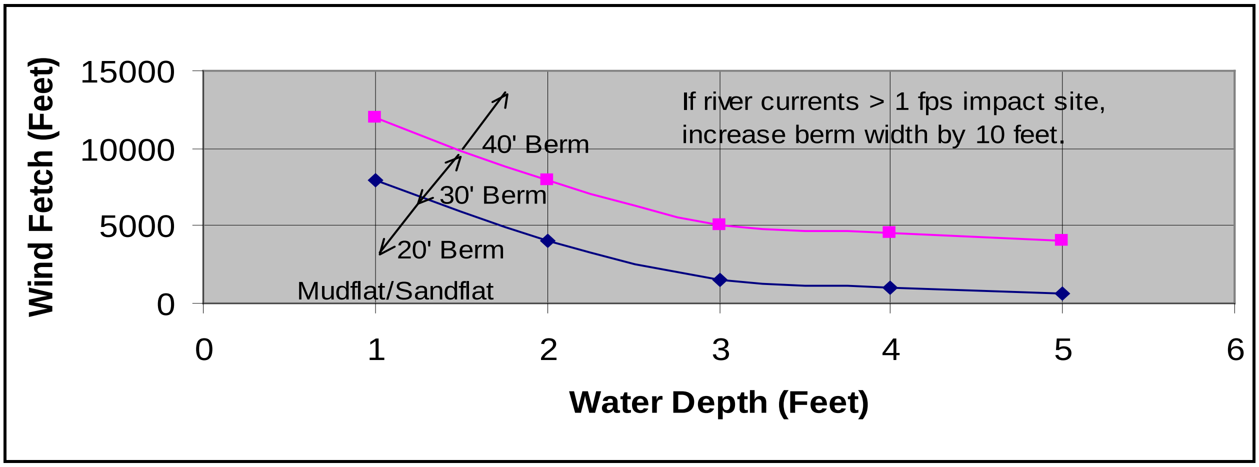

Figure 9-C-1. Berm Width Versus Wind Fetch and Water Depth

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.

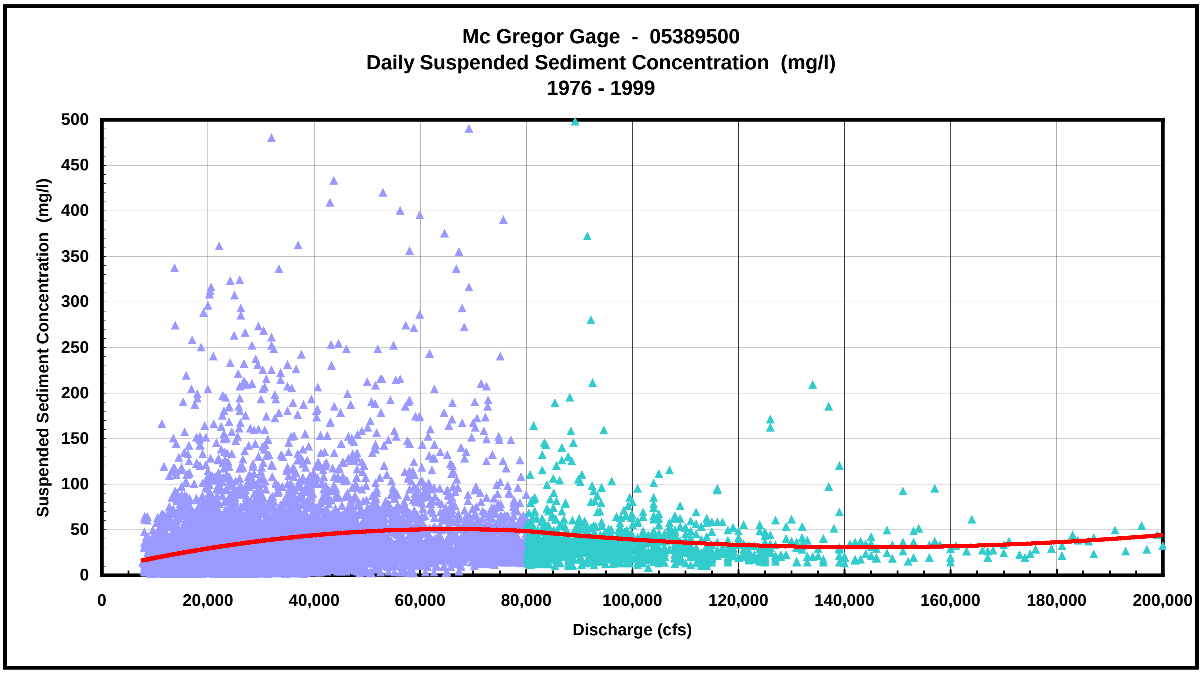

Figure 9-C-2. Data Showing Relatively Low Concentrations That Occur at Higher Discharges (McGregor, IA)

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.

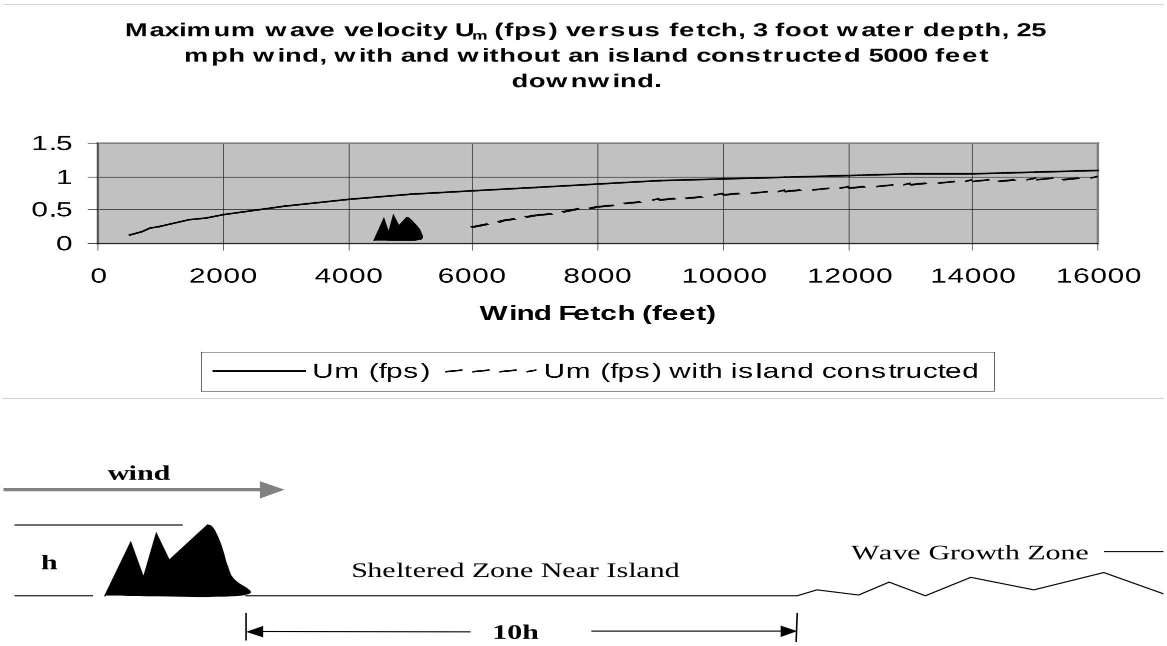

Figure 9-C-3. Wind driven wave velocity and sheltered zone down-wind of an island.

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.

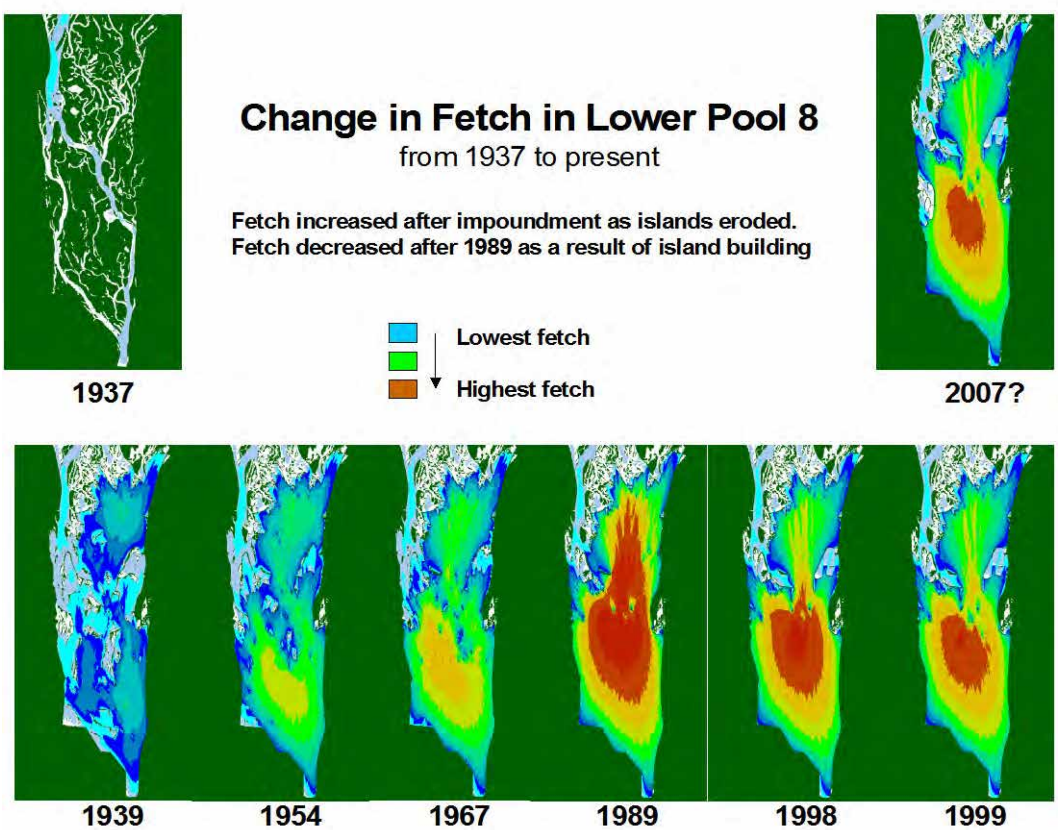

Figure 9-C-4. Changes in Fetch in Lower Pool 8, 1937 to 2007

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

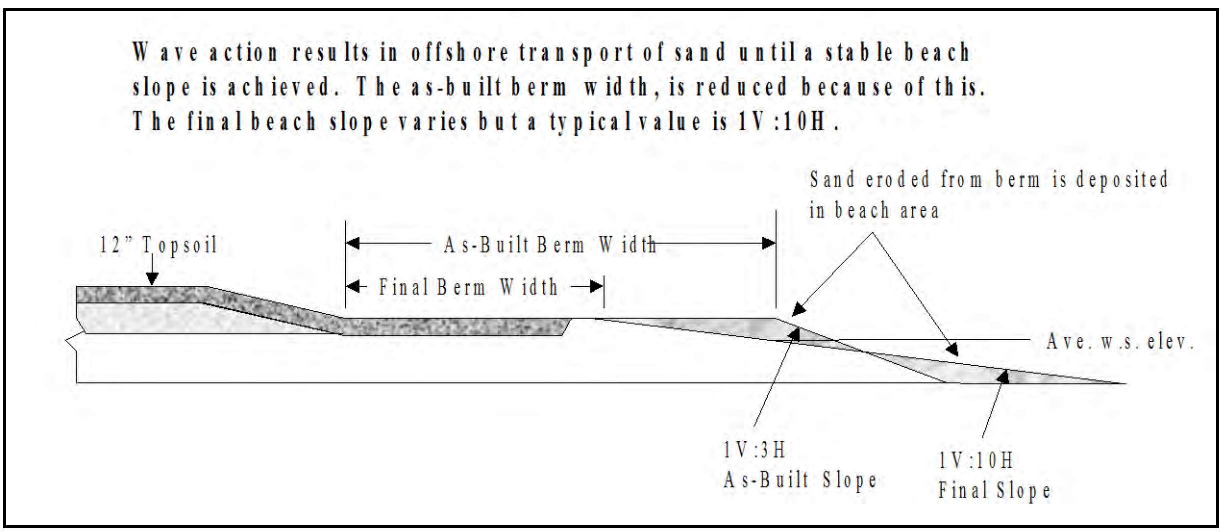

Figure 9-C-5. Reshaping of the Islands Shoreline Due to Wave Action

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.

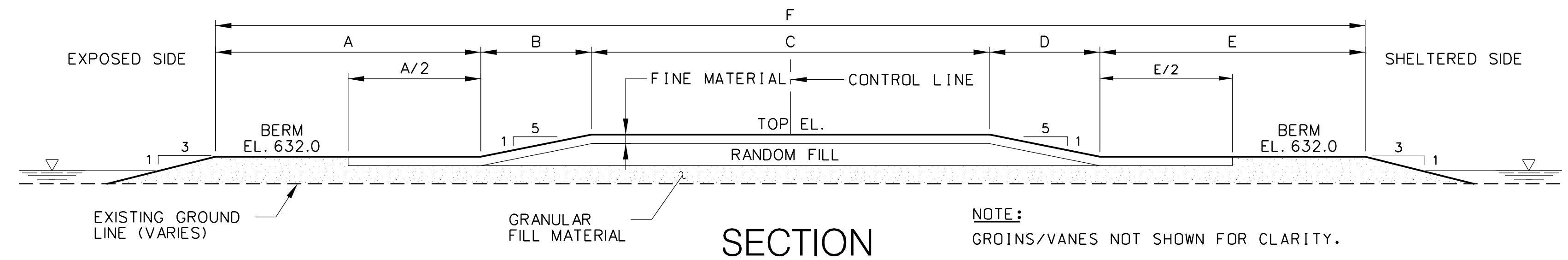
[3]Phase III data is from Scott Baker presentation given on Feb22 at St. Paul District Office. For stage 3A, 340,000 yd3 of granular, and 37,000 yd3 of fines. For stage 3B 165,000 yd3 granular, 16,000 yd3 fines, 20,000 tons of rock (16,000 tons for the rock sill)

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

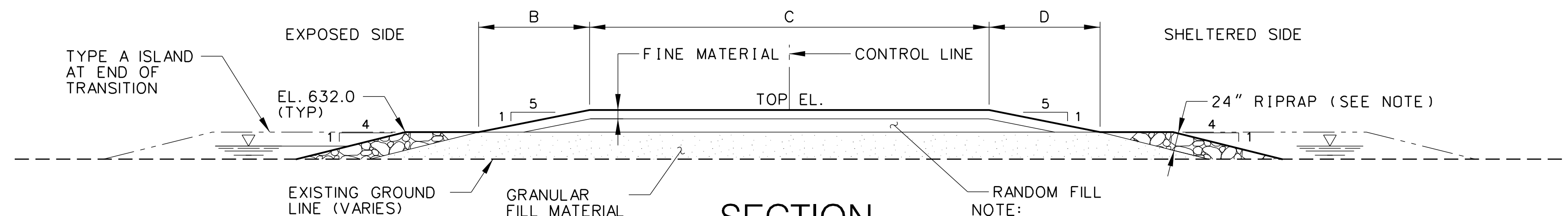


SECTION

TYPE A ISLAND

NOTE:

GROINS/VANES NOT SHOWN FOR CLARITY.

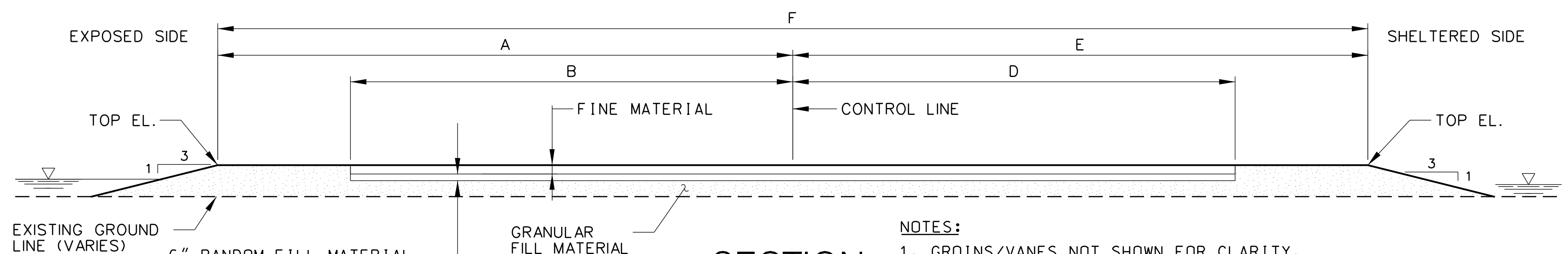


SECTION

TYPE A-1 ISLAND

NOTE:

THE INCLUSION OF RIPRAP AND ITS LOCATION WILL VARY BY ISLAND. SEE INDIVIDUAL ISLAND PLANS FOR LOCATION.

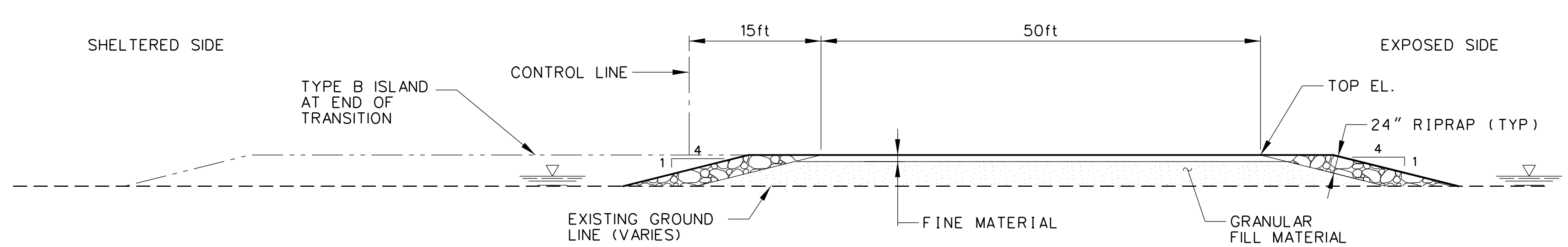


SECTION

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.

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PLOT DATE: No
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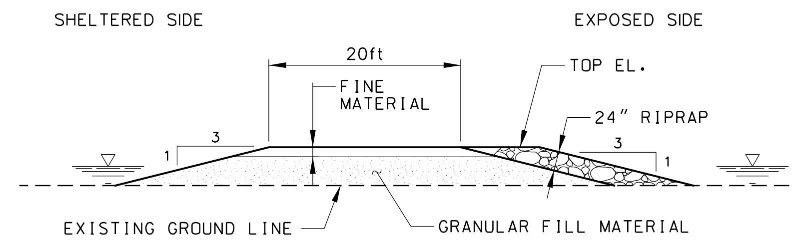
SIZE: D
FILE NAME:

HABITAT REHABILITATION AND ENHANCEMENT
MISSISSIPPI RIVER
ISLAND DESIGN MANUAL STANDARD DETAILS

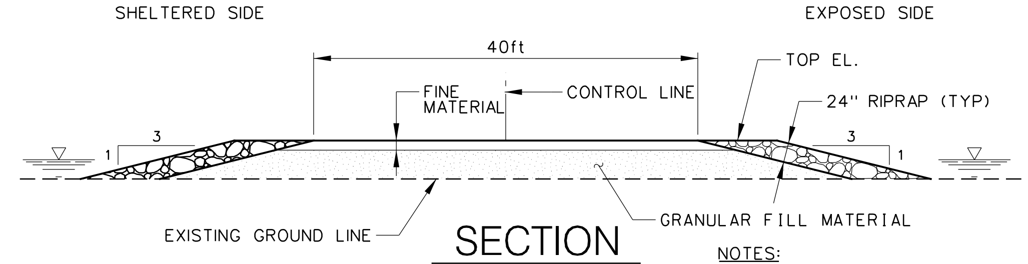
ISLAND TYPES A & B

SHEET IDENTIFICATION
PLATE I



SECTION

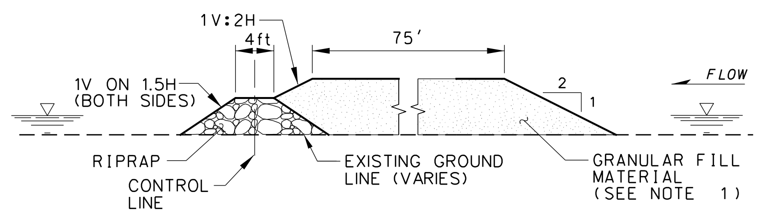
TYPE C ISLAND



SECTION

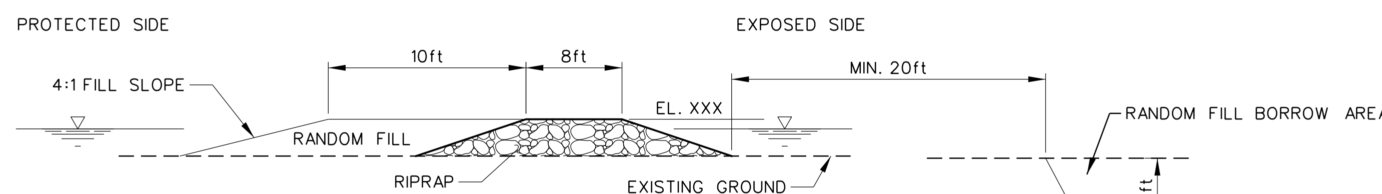
TYPE C ISLAND
(SECTION AT END OF ISLAND)

NOTES:
1. GROINS/VANES NOT SHOWN FOR CLARITY.



SECTION

TYPE D - SEED ISLAND

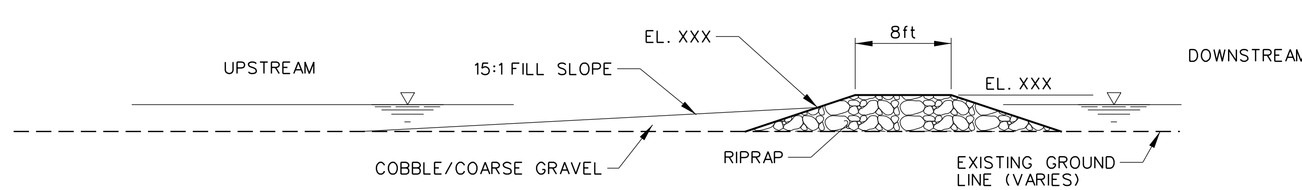


NOTES:

1. ALL ROCK FILL SLOPES SHALL BE 1V:2H.

SECTION

TYPE E ISLAND



NOTES:

1. ALL ROCK FILL SLOPES SHALL BE 1V:2H.

SECTION

TYPE F ISLAND
FISH SPAWING HABITAT

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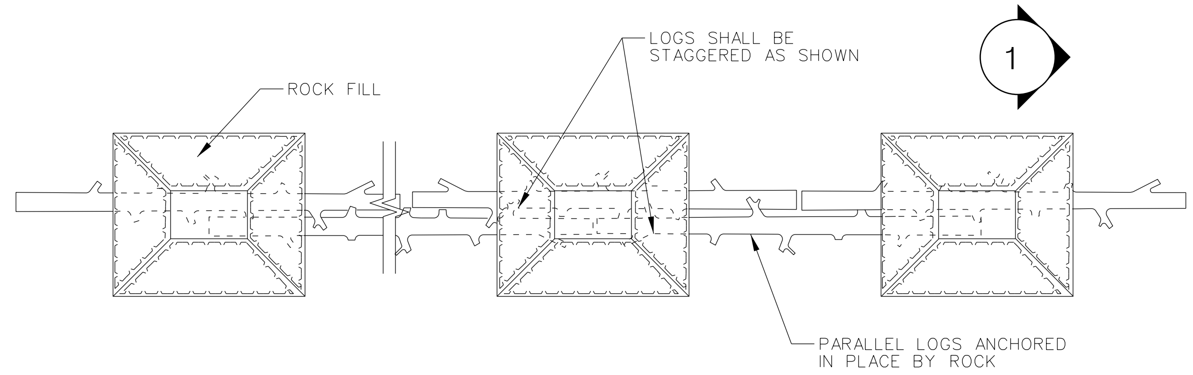
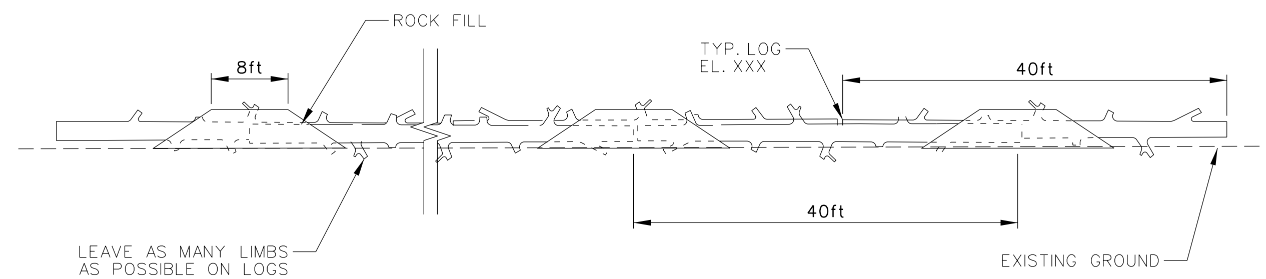
ISLAND TYPES C, D, E & F

SHEET IDENTIFICATION
PLATE 2

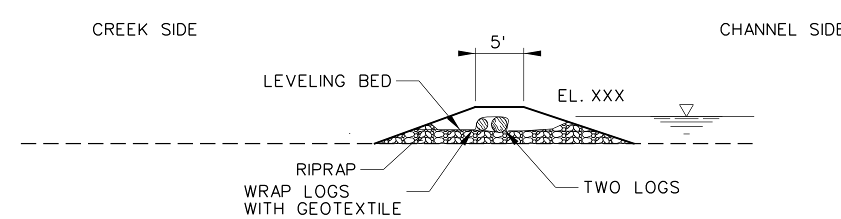


PLAN VIEW



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.

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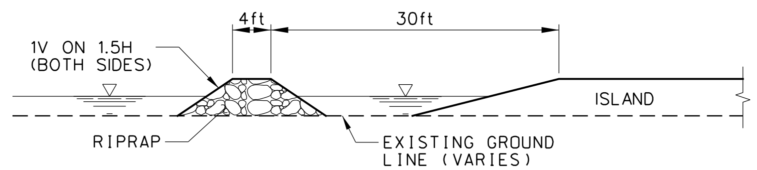
HABITAT REHABILITATION AND ENHANCEMENT
MISSISSIPPI RIVER
ISLAND DESIGN MANUAL STANDARD DETAILS

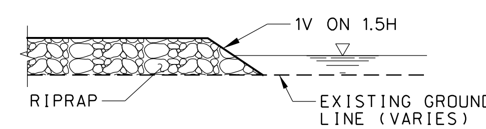
ROCK/LOG ISLAND

SHEET IDENTIFICATION
PLATE 3

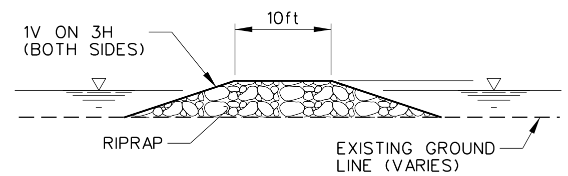


SECTION
ROCK MOUND ALONG ISLAND

0 10' 20'

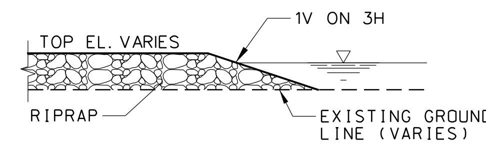


LONGITUDINAL SECTION
THRU ROCK MOUND AT END (TYP)



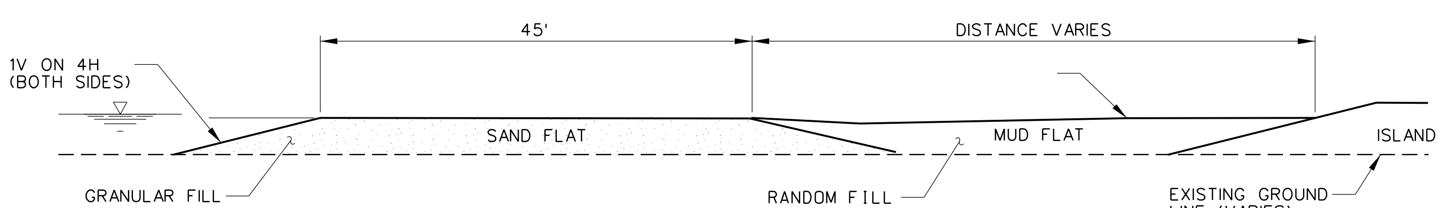
SECTION
ROCK SILL

0 10' 20'



LONGITUDINAL SECTION
THRU ROCK SILL AT END (TYP)

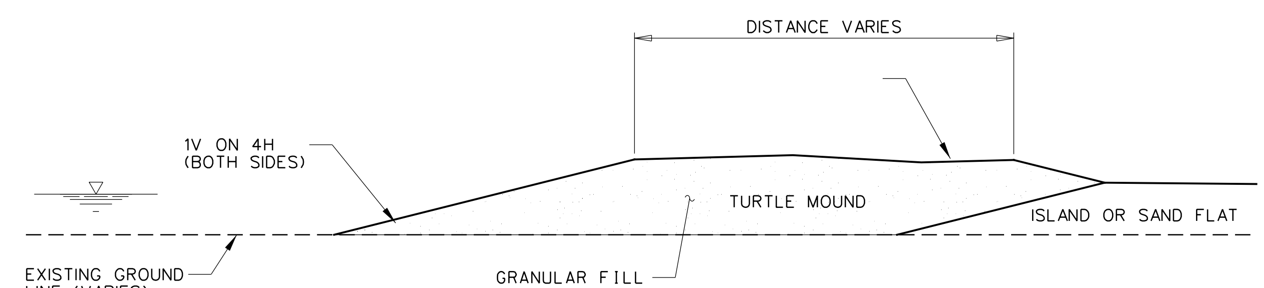
NOTES:
1. PLACE 6 INCHES OF CHINKING STONE ON UPSTREAM (UNPROTECTED) SLOPE OF ROCK SILL.



NOTES:

SECTION
THRU SAND FLAT & MUD FLAT

0 10' 20'



SECTION
TYPICAL TURTLE MOUND

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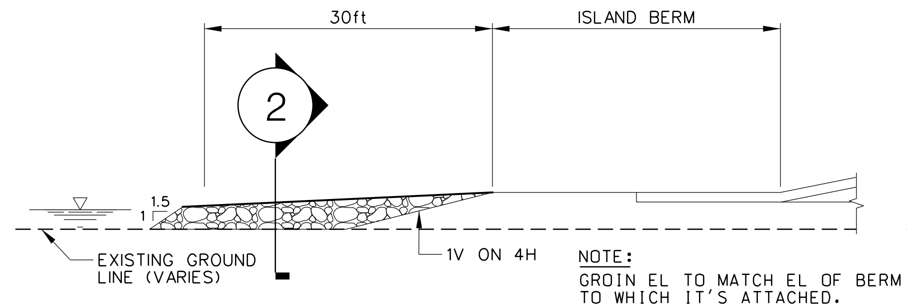
MISSISSIPPI RIVER
ISLAND DESIGN MANUAL STANDARD DETAILS

ROCK MOUND, ROCK SILL, MUD/SAND FLATS & TURTLE NESTING MOUND

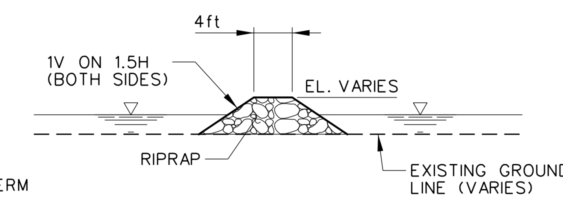
SHEET IDENTIFICATION
PLATE 4



ELEVATION

TYPICAL ROCK GROIN

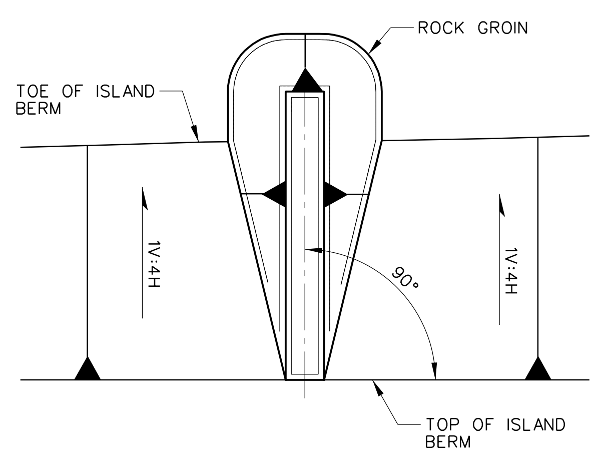
0 10' 20'



2 SECTION

TYPICAL ROCK GROIN/VANE

0 10' 20'



PLAN

TYPICAL ROCK GROIN

0 10' 20'

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FILE NAME:
DATE:
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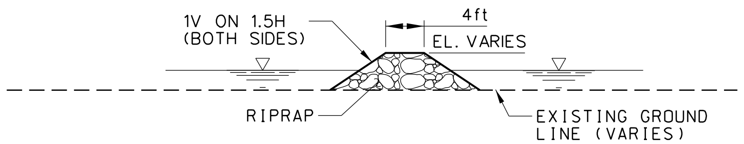
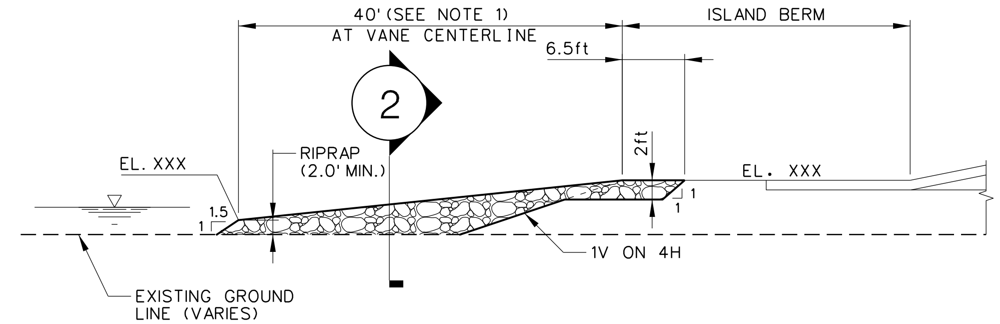
MISSISSIPPI RIVER
ISLAND DESIGN MANUAL STANDARD DETAILS

ROCK GROINS

SHEET IDENTIFICATION
PLATE 5

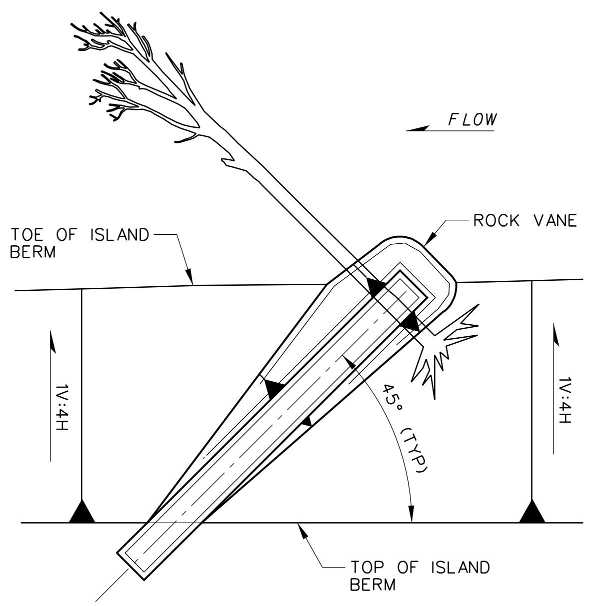


2 SECTION
TYPICAL ROCK VANE
0 10' 20'

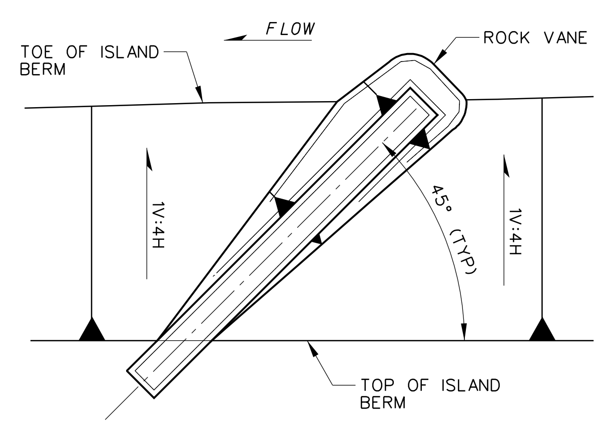


NOTE:
1. DISTANCE VARIES FOR J-HOOK VANES.

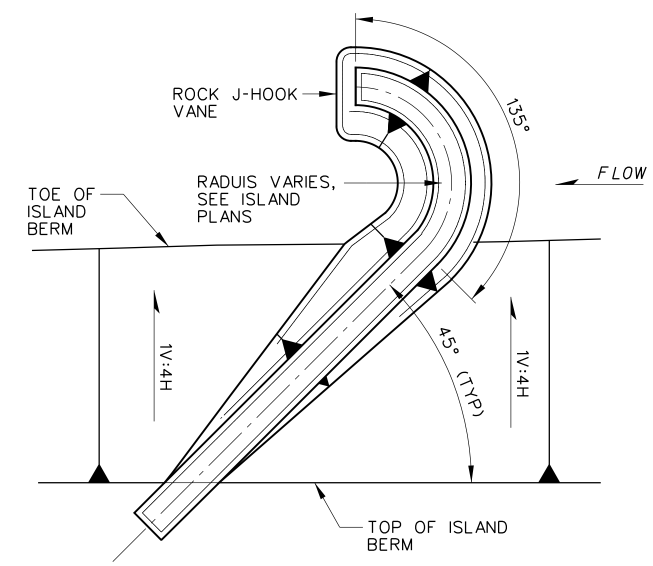
PROFILE
TYPICAL ROCK VANE
0 10' 20'



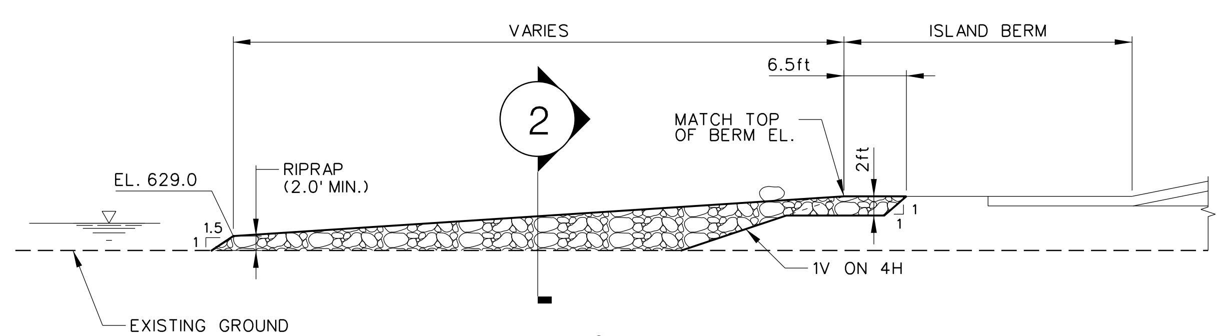
PLAN
TYPICAL ROCK VANE
0 10' 20'



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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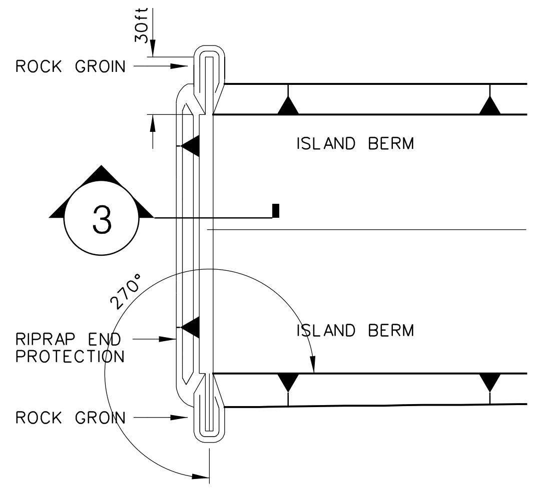
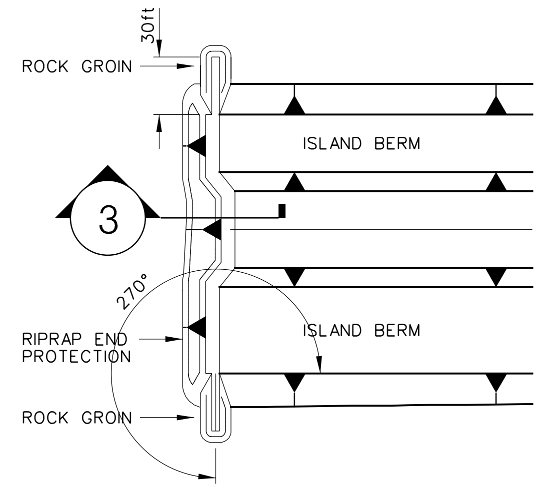
ROCK VANES
J-HOOK AND STANDARD

SHEET
IDENTIFICATION
PLATE 6



PLAN

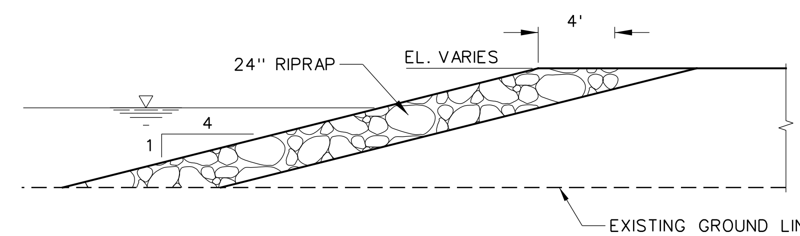
RIPRAP END PROTECTION
TYPE B ISLAND



PLAN

RIPRAP END PROTECTION
TYPE A ISLAND

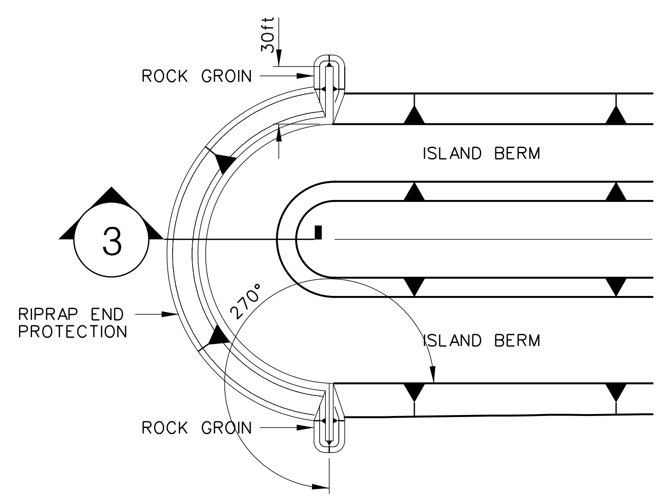
0 25' 50' 100'



3 SECTION

ISLAND RIPRAP END/BANK PROTECTION

0 25' 50' 100'



PLAN

RIPRAP END PROTECTION - ROUND

0 25' 50' 100'

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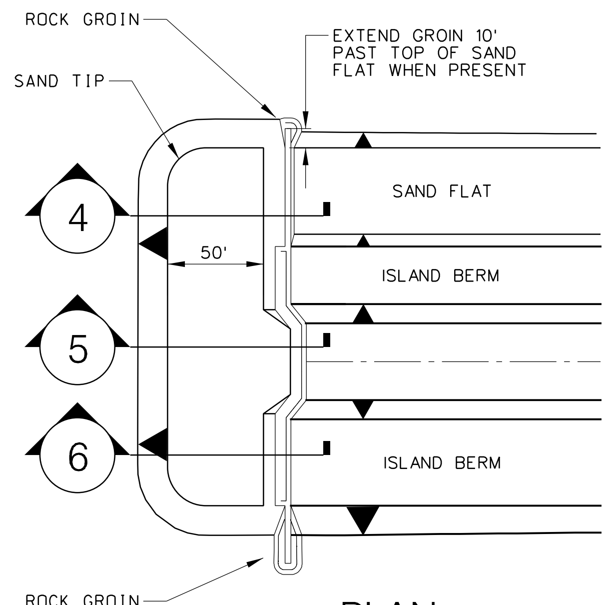
ISLAND END PROTECTION
PLAN AND SECTION

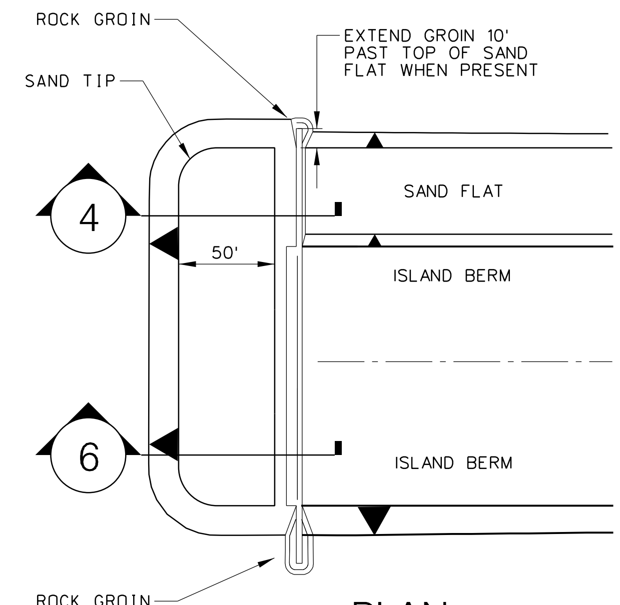
SHEET IDENTIFICATION
PLATE 7



PLAN

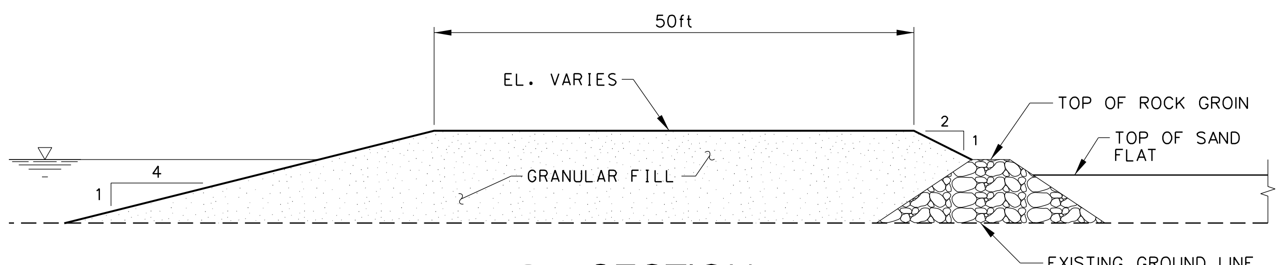
RIPRAP END PROTECTION
WITH SAND TIP
TYPE A ISLAND

0 25' 50' 100'



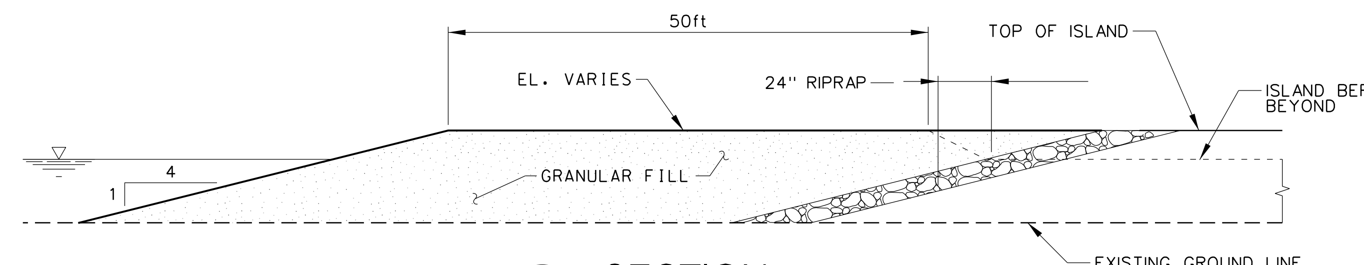
PLAN

RIPRAP END PROTECTION
WITH SAND TIP
TYPE B ISLAND



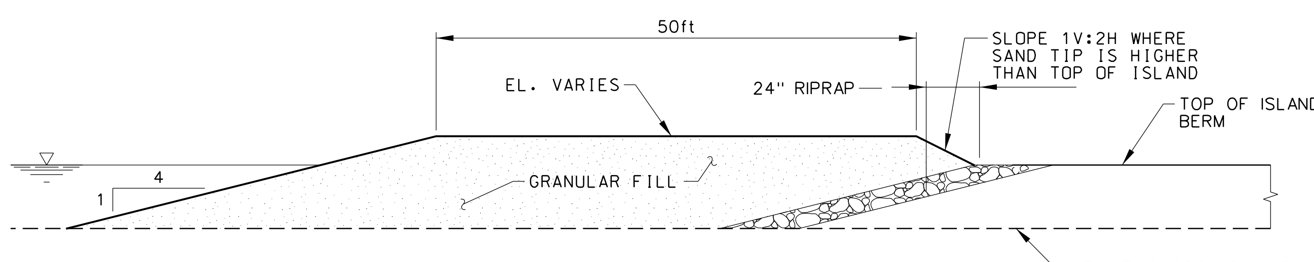
4 SECTION

SAND TIP ALONG ROCK GROIN



5 SECTION

SAND TIP AT TOP OF ISLAND



6 SECTION

SAND TIP ADJACENT TO ISLAND BERM

0 25' 50' 100'

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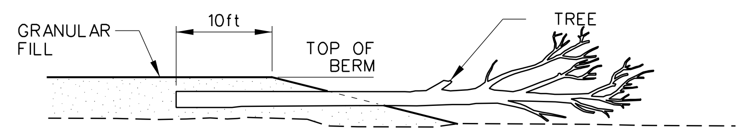
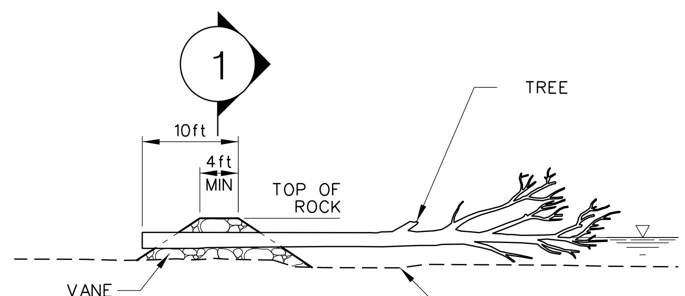
ISLAND SAND TIP

SHEET IDENTIFICATION
PLATE 8



SECTION
TYPE 1 ANCHORAGE WILDLIFE LOAFING STRUCTURE

0 10' 20'



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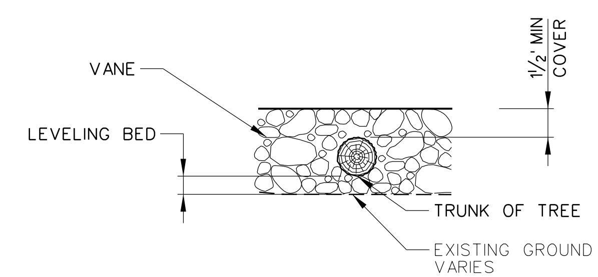
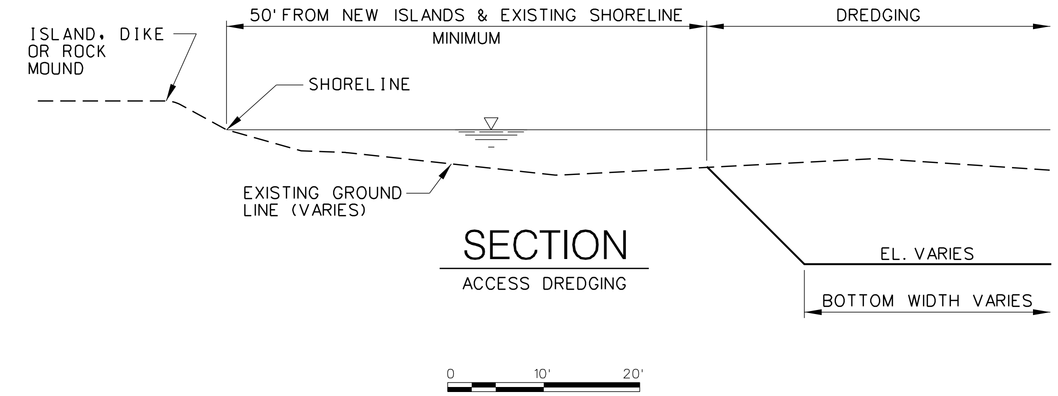
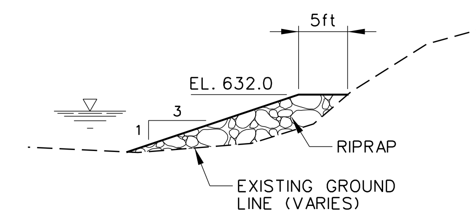


1 SECTION
0 5' 10'



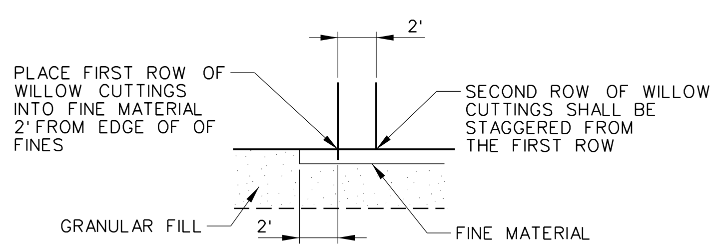
SECTION
ACCESS DREDGING

0 10' 20'



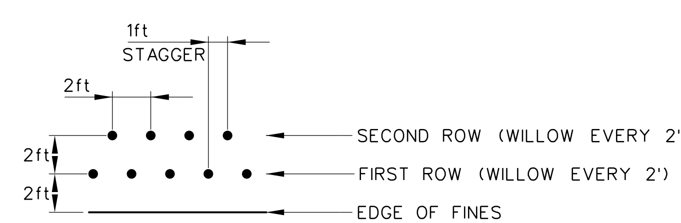
TYPICAL SECTION
RIPRAP BANK STABILIZATION

0 10' 20'



SECTION
WILLOW PLANTING

5' 2.5' 0 5'



PLAN
WILLOW PLANTING

5' 2.5' 0 5'

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:
DATE:
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

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.

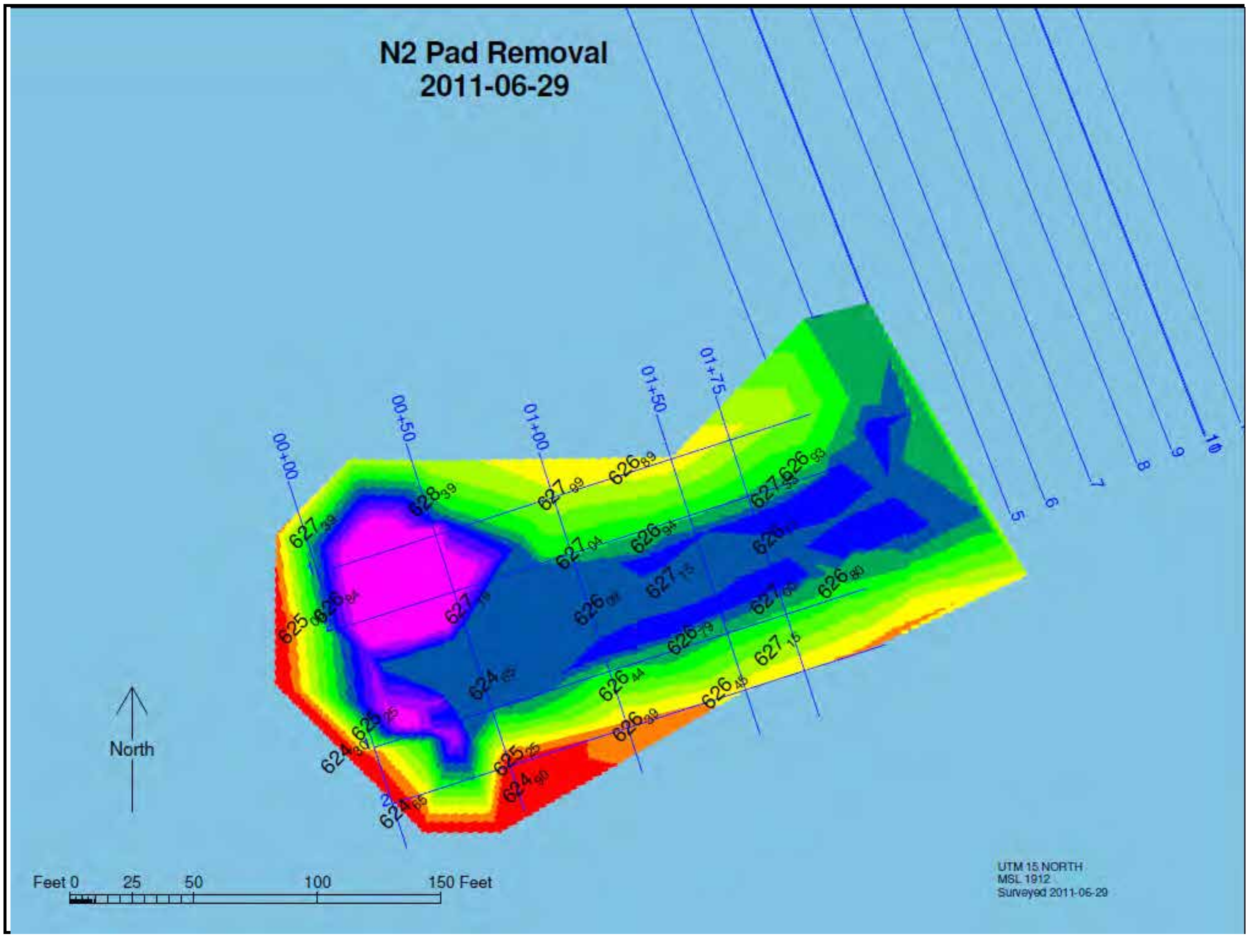


Figure 9-F-1. Access Pad – Post-Removal Survey (Typical)

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.

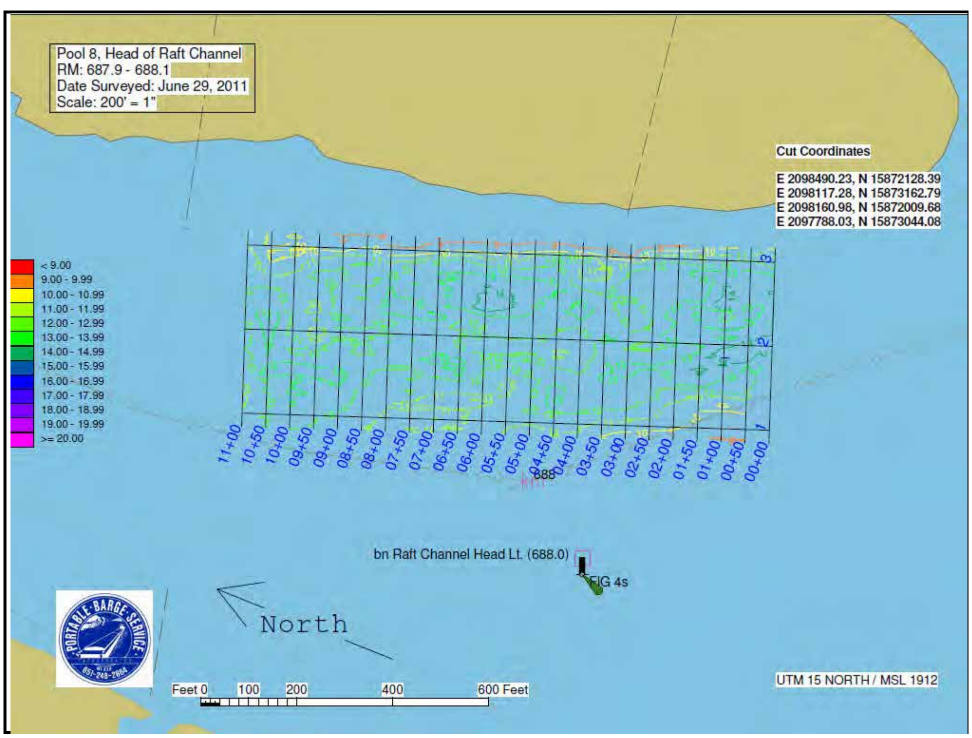


Figure 9-F-2. Main Channel Granular Borrow – Post-Dredge Survey (Typical)

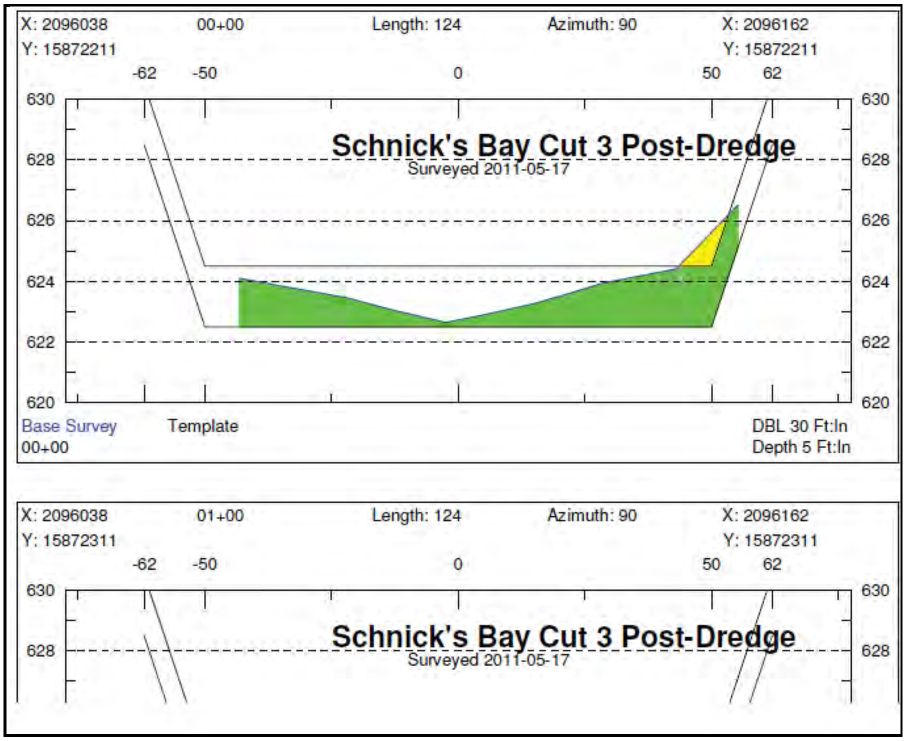


Figure 9-F-3. Fine Borrow Area – Post-Dredge Survey (Typical)

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

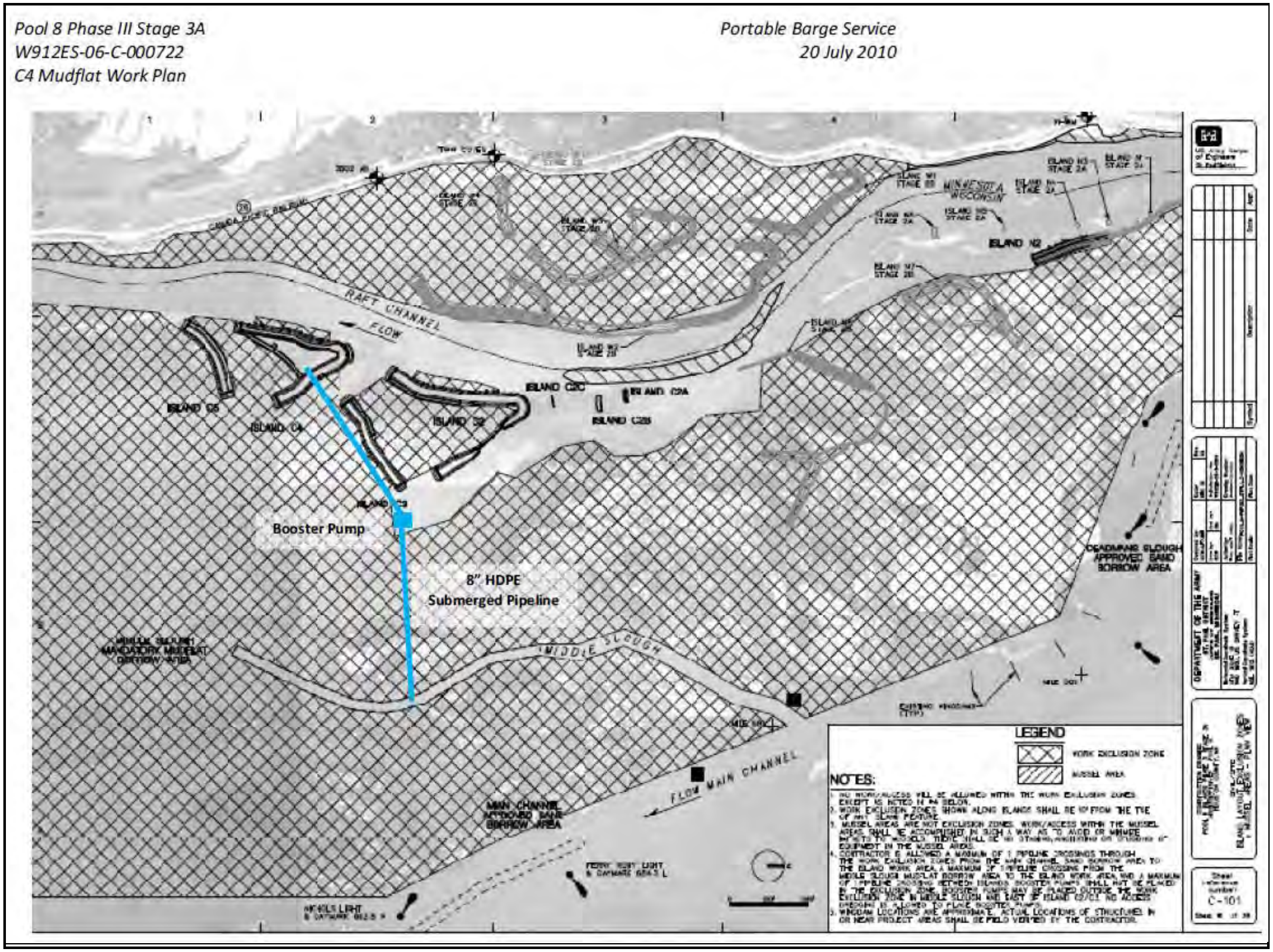


Figure 9-F-4 Emergent Wetland Work Plan – Stage 3A

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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