UPPER MISSISSIPPI RIVER SYSTEM
ENVIRONMENTAL DESIGN HANDBOOK

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UPPER MISSISSIPPI RIVER SYSTEM
ENVIRONMENTAL DESIGN HANDBOOK

CHAPTER 9

ISLANDS

9.1 Resource Problem

The Upper Mississippi River (UMR) is island braided with many anastomosing 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 its natural condition (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 today and island construction is an attempt to reverse or alter the impacts of the locks and dams.

Construction of the locks and dams submerged portions of the natural levees and floodplain creating navigation pools upstream of the dams and leaving only the higher parts of the natural levees as islands. Table 9.1 shows the effect of submergence on parameters describing hydrodynamics, sediment transport, and geomorphology in the lower reaches of navigation pools. A more detailed discussion on these physical changes can be found in Appendix C.

Appendices to this chapter include a discussion on Physical River Attributes (Appendix A); Habitat Parameters (Appendix B); Engineering Considerations (Appendix C); Project Photographs (Appendix D); and Standard Details (Appendix E).

Table 9.1. Lock and Dams Effects and Island Effects on Parameters Describing Hydrodynamic, Sediment Transport, and Geomorphic Regimes in the Lower Reaches of Pools in Pools 1 Through 13 of the UMRS

Parameter	Definition	Lock and Dam Effects	Island Effects
Q_c	Channel discharge including secondary channels	- [1]	+ [2]
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 two-year flood and low flow	-	
F	Wind fetch in floodplain	+	-
Q_s	Sediment load	-	+
SS	Suspended sediment concentration	+	-
D_c	Sediment deposition rate in channels	+, -	-
D_f	Sediment deposition rate in floodplains	+	-
E_c	Channel bed erosion rate	-	+
E_b	Bankline erosion rate	+	-
E_f	Floodplain erosion rate	+	-
d_{50}	Sediment particle size in channels	-	+

[1] + indicates that magnitude of parameter increased
[2] - indicates that magnitude of parameter decreased

The physical changes created by lock and dam construction produced a significant biological response in the lower reaches of the navigation pools. The original floodplain, which consisted of floodplain forests, shrub carrs, wetlands, and potholes, was converted into a large permanently submerged aquatic system. These areas are commonly called *backwaters*. A diverse assemblage of aquatic plants colonized the backwaters, with the distribution of plant species being a function of water depth, current velocity, and water quality. Fish and wildlife flourished in this artificial environment for several decades after submergence; however, the following factors caused a gradual decline in the habitat that had been created in the backwaters.

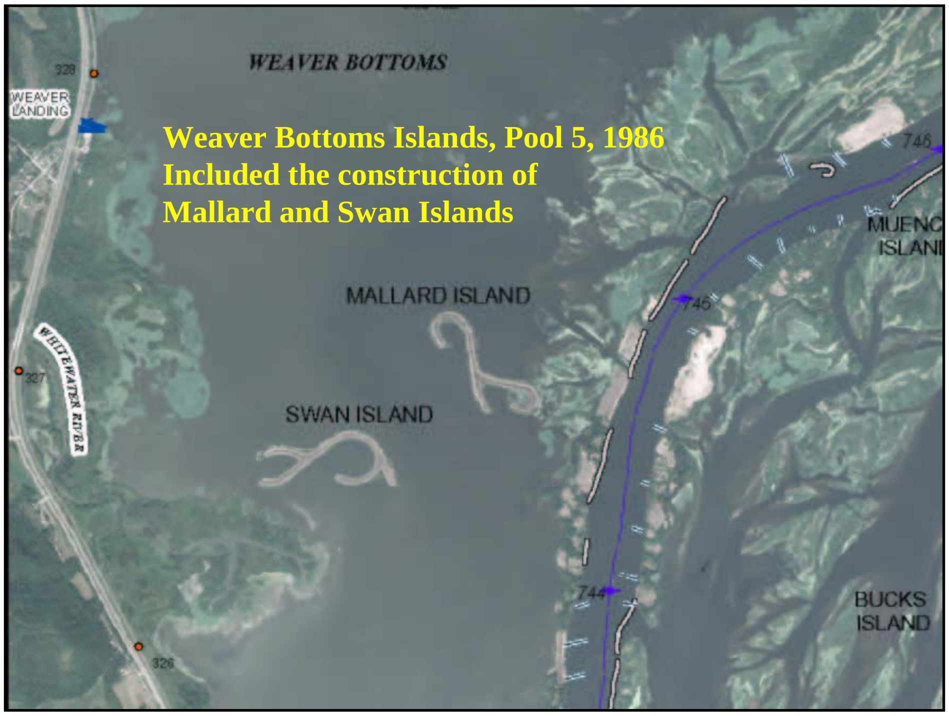
Sediment Deposition. With permanent submergence in the lower reaches of the navigation pools came the continual flow of water into the floodplain areas. As flow spread out in the backwaters, it lacked the energy to transport sediment through the backwaters, resulting in a depositional system. Sediment deposition was greatest near sediment sources such as the main channel, secondary channels, and tributaries. In numerous areas deltas have formed near these sediment sources and the habitat quality in these deltas is generally good. However, in most areas, sediment deposition has filled in aquatic habitat, and altered substrate characteristics so that aquatic plant growth is reduced. The system that was created by the locks and dams simply was not sustainable.

Permanent Submergence. Aquatic plants will colonize areas that have the right combination of water depth, velocity, and quality. Some species exist in low areas that are permanently submerged, while others exist at higher elevations that are submerged some of the time and are dry at other times. Variability in the annual water level hydrograph creates the condition that supports diverse aquatic plant communities. The problem in the lower reaches of the navigation pools is that there is little variation in water levels between low flow conditions and the bankfull flood. Maintaining a minimum pool elevation results in little area that ever dries out. Without this variability, and especially without the drought portion of the annual hydrograph, habitat quality has declined.

Island Erosion. The islands that remained after the locks and dams were constructed were exposed to erosive forces from wind driven wave action, river currents, and ice action. As islands eroded, the amount of open water increased and the magnitude of the erosive forces increased. This was exacerbated by the loss of aquatic vegetation, which created even more open water.

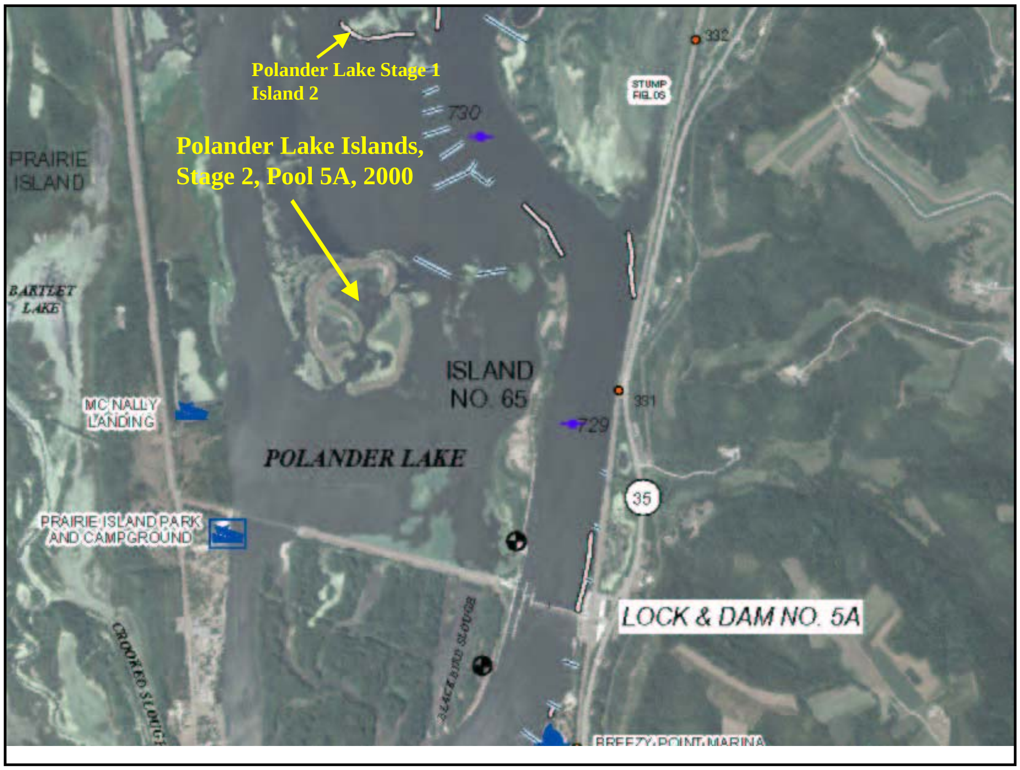
The effects of sediment deposition, loss of aquatic plant communities, and island erosion has resulted in degraded habitat in the lower reaches of the navigation pools. While project goals and objectives usually focus directly on the improvement of habitat in the floodplain, the physical impact of island construction is to partially restore riverine hydrodynamic, sediment transport, and geomorphic conditions. As table 9.1 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. This increases the velocity and transport of sediment in adjacent channels. Wind fetch and wave action is reduced in the vicinity of islands, reducing the resuspension of bottom sediments, floodplain erosion, and shoreline erosion. Earlier islands were designed to reduce the supply of sediment to the floodplain, potentially decreasing floodplain sediment deposition. More recent island projects have taken a more realistic approach toward “managing” sediment transport and deposition by designing islands to promote both scour and deposition as a means to improve sustainable habitat quality and diversity. 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.

9.2 Plan Views of Island Projects

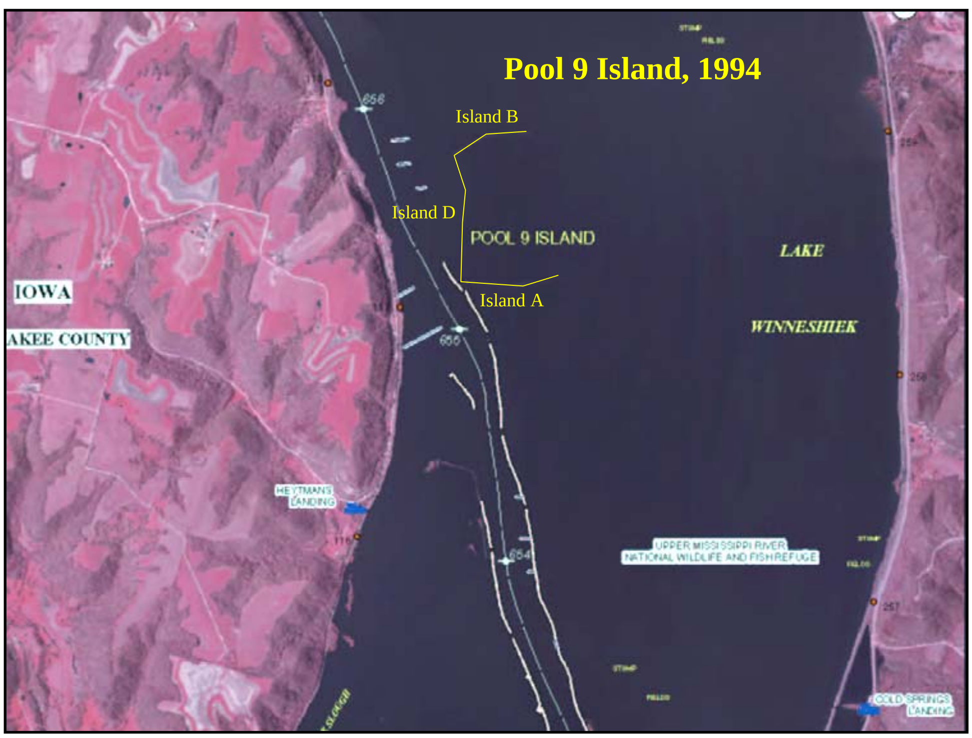


Photograph 9.1. Weaver Bottoms Island, Pool 5, Mississippi River

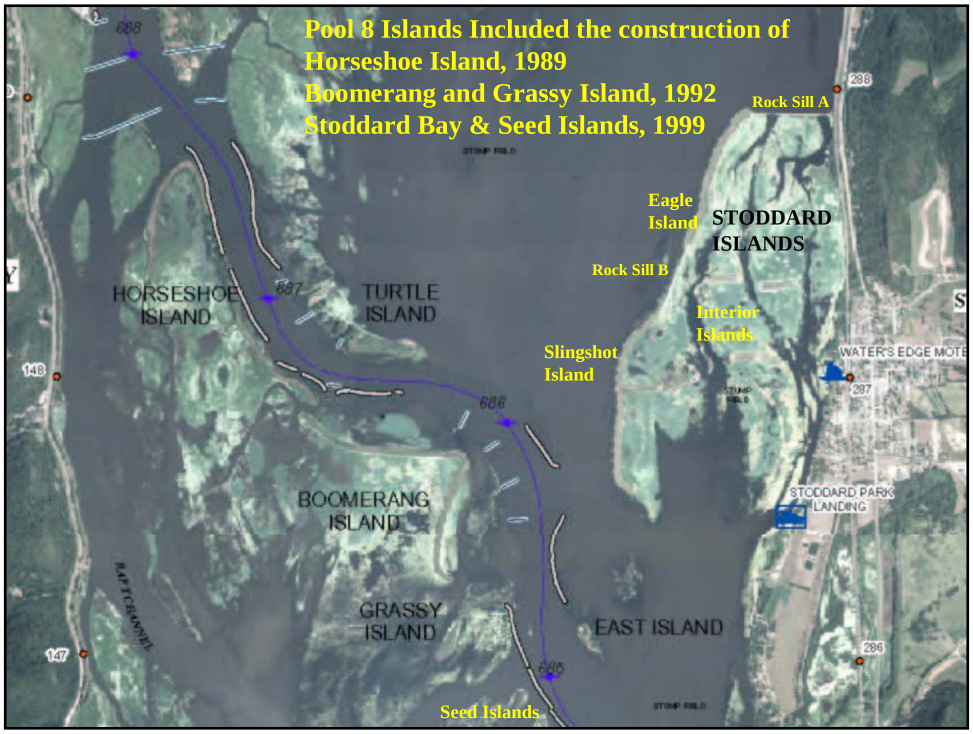
Photograph 9.2. Lake Onalaska Islands, Pool 17, Mississippi River



Photograph 9.3. Polander Lake Islands, Pool 5A, Mississippi River



Photograph 9.4. Pool 9 Island, Pool 9, Mississippi River



Photograph 9.5. Pool 8 Islands, Pool 8, Mississippi River

Photograph 9.6. Willow Island

Photograph 9.7. Peoria Lake Islands, Peoria Pool, Illinois River

Photograph 9.8. Pool 11 Islands, Sunfish Lake, Mississippi River

Photograph 9.9. Swan Lake Islands, Illinois River

9.3. Engineering, Design, and Construction Data for Existing Island Projects

9.3.1. Island Cross Section. Figure 9.1 shows a typical island cross section (though many exceptions exist). Islands have a main section (dimension c) with berms on either side (dimensions a & e). The elevation and width of the main section is a function of habitat objectives, engineering considerations such as flood conveyance needs, 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 head 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. The berms 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. Because the berms are usually lower than the main section of the island, they provide elevation diversity also.

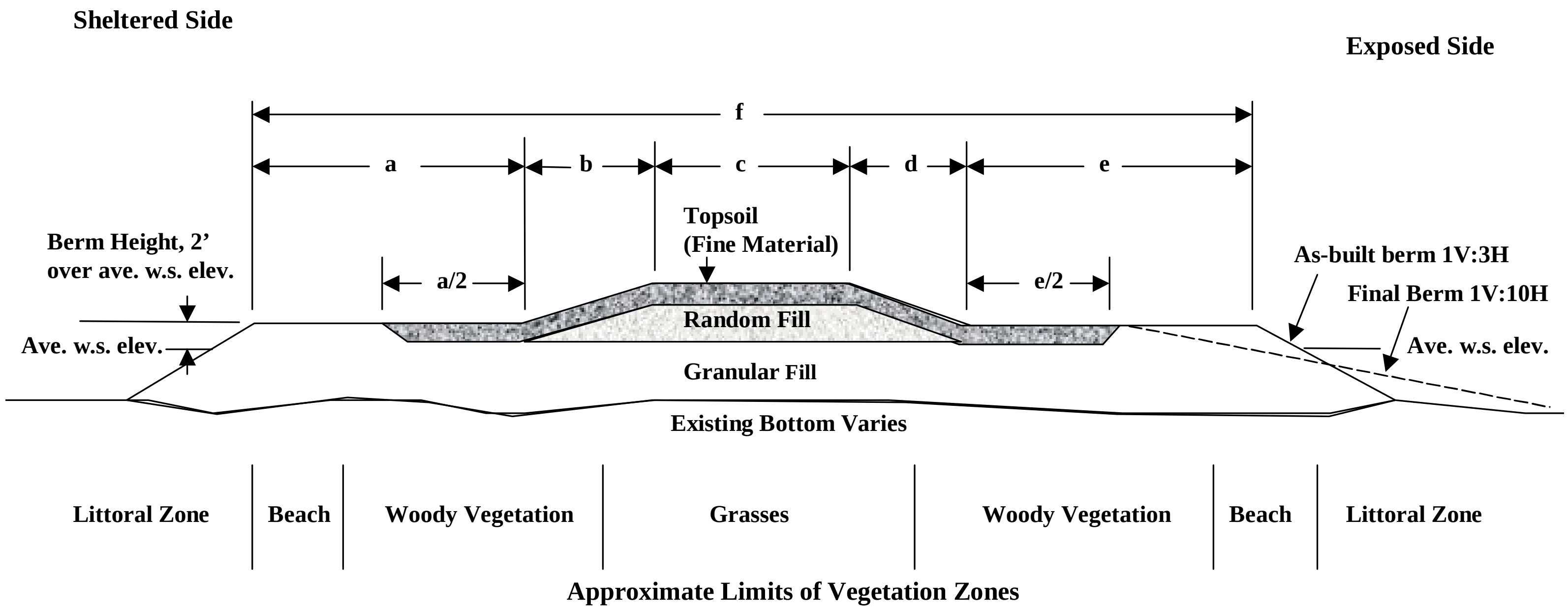


Figure 9.1. Typical Island Cross Section

Islands in the northern reaches of the UMR are usually constructed with sand (granular fill) and mixtures of fine sediments and sand. The mixtures are called by various terms including fine material, random fill, topsoil, fines, and select fines. Fine sediments are defined as silts and clay size material passing the no. 200 sieve or the .075 mm sieve. Table 9.2, which provides information on the quantities of sand and fines that were used on three island projects, indicates that islands consist of approximately 75 percent sand and 25 percent fines. The base of the island is constructed of sand to provide a stable work surface for construction equipment; 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 (photograph 9.10).

Table 9.2. Sand and Fines Quantities on Three Island Projects

	Pool 8, Phase I	**Pool 8, Phase II**	**Polander Lake**
Island Length (feet)	8,700	10,400	9,200
Sand (cubic yards)	157,000	207,000	176,000
Random Fill (cubic yards)			33,000
Fine Material (cubic yards)	56,000	66,000	30,000
Total Fill (cubic yards)	213,000	273,000	239,000
Percent Sand	74	76	74
Total fill/foot of length (cubic yards)	24.5	26.3	26.0

Photograph 9.10. Pool 8, Phase I, Stage II, Boomerang Island
Fine sediments have been placed on top of a sand base to form a topsoil layer. These fine sediments were mechanically excavated and placed on the island (as opposed to hydraulic placement)

Because of a difference in material types, islands in the southern reaches of the UMR and Illinois River have been constructed using fine sediments (i.e. no sand base). At both Peoria Lake and Swan Lake, islands were created from sediment that was dredged mechanically from nearby channels. The specifications for both of these projects called for the contractor to use a large bucket (e.g. 7 CY at Peoria Lake) for mechanical excavation. This was done so that the fine sediments would be placed in larger masses, preserving some of the 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 three lifts. Information regarding properties of the borrow material, such as percent fines, is not available.

Table 9.3 provides design dimensions for constructed island projects. The variables "a" through "f" are as shown in figure 9.1. The top elevation is listed and the corresponding flood that would overtop that elevation. The two side slopes that are listed are for the exposed or channel side and the sheltered or floodplain side of the island. The distribution of top elevations versus flood frequency is shown in figure 9.2. Generally, top elevations have decreased with each successive project, and the variability of elevations has increased.

Table 9.3. Island Cross Section Dimensions

Project	a	b	c	d	e	f	Height Above Normal Pool and Flood Time of Return	Side Slopes V: H	Island Length and Reach Description (ft)	Year
Weaver Bottoms	0	32	100	32	0	164	8, 80-yr	1:4 1:4	8700	1986
Lake Onalaska	0	18	50	9	20	100	6, 20-yr	1:3 1:3	3900, 3 islands at 1300 feet each	1989
Pool 8, Phase I, Stage 1, Horseshoe Island	0	20	50	30	30	130	4, 10-yr	1:5 1:10	2100, from head down each leg	1989
	0	20	75	30	30	155	4, 10-yr	1:5 1:10	800, middle west leg	1989
	0	20	30	40	0	90	4, 10-yr	1:5 1:10	600, lower west leg	1989
Bertom McCartney										1992
Pool 8, Phase I, Stage 2, Boomerang Is.	30	12	50	12	30	134	3.8, 10-yr	1:5 1:5	7000	1992
	20	12	50	12	20	114	3.8, 10-yr	1:5 1:5	700, several reaches	1992
	30	10	50	40	0	130	3.8, 10-yr	1:4 1:10	500, large fines section	1992
	0	25	30	25	0	80	5, 17-yr	1:5 1:5	500, lower Horseshoe Island	1992
Pool 8, Phase I, Stage 2, Grassy Island	0	6	50 -150	6	0	62 - 162	2, 5-yr	1:3 1:3	900	1992
Pool 9, Island A & B [2]	na	3.4	5	3.4	na	12	1.5, 1.6-yr	1:1.7 1:1.7	3800	1994
Pool 9, Island D [2]	na	2	5	2	na	9	.5, 1.3-yr	1:2 1:2	2900	1994
Polander Lake, Stage 1, Island 2 [2]	na	9	4	9	na	22	2, 1.8-yr	1:3 1:3	1100	1994
Willow Island	30	25	10	21	0	86	7, 10-yr	1:5 1:3	2800	1995
	0	17	10	21	0	48	7, 10-yr	1:2.51:3	900, riprap reach	1995
Peoria Lake Islands	0		50		0		8	1:6	5280	1996
Swan Lake, Illinois River	0	45	25	45	0	115	5	1:6 1:6	9 islands 180’ to 500’ long	1996
Pool 8, Phase II, Eagle Island	33	13	50	13	33	142	4, 10-yr	1:5 1:5	2800	1999
Pool 8, Phase II, Slingshot Island	33	8	33	8	20	102	3, 7-yr	1:5 1:5	3300, Upper Slingshot Island	1999
	33	7	33	7	33	113	2.7, 6-yr	1:5 1:5	1200, Middle Slingshot Island	1999
	33	3	33	3	33	105	2, 5-yr	1:5 1:5	900, Lower Slingshot Island	1999
Pool 8, Phase II Interior Islands	33	13	33	13	20	112	4, 10-yr	1:5 1:5	2400	1999
Pool 8, Phase II Rock Sills [2]	na	6	13	3	na	22	1, 2.5-yr	1:4 1:2	2500	1999
Polander Lake, Stage II	40	17.	20	17.	30	125	5, 4-yr	1:5 1:5	3800	2000
	40	27.	20	27.	30	145	7, 8-yr	1:5 1:5	1200	2000
Polander Lake, Stage II, Interior Islands	20	20	20	12	20	92	3.5, 2.5-yr	1:5 1:3	4200	2000
Pool 11 Sunfish Lake									5000	2004
Pool 11, Mud Lake								1:5 1:5		2005
Spring Lake, Island 2	20	5	40	5	45	115	3, 8-yr	1:5 1:5	2400	2005
Spring Lake, Island 3	20	10	45	10	30	115	4, 15-yr	1:5 1:5	850	2005
Spring Lake, Island 3	40	0	65	0	40	145	2, 6-yr	-	1400	2005
Spring Lake, Island 3	0	0	60	0	0	60	2.5, 7-yr	-	1250	2005
Spring Lake, Island 4	0	0	115	0	0	115	662.5, 7-yr	-	2050	2005

[1] Note: Elevations are NGVD, 1912 adj. Dimensions are in feet.

[2] These islands were constructed entirely of rock.

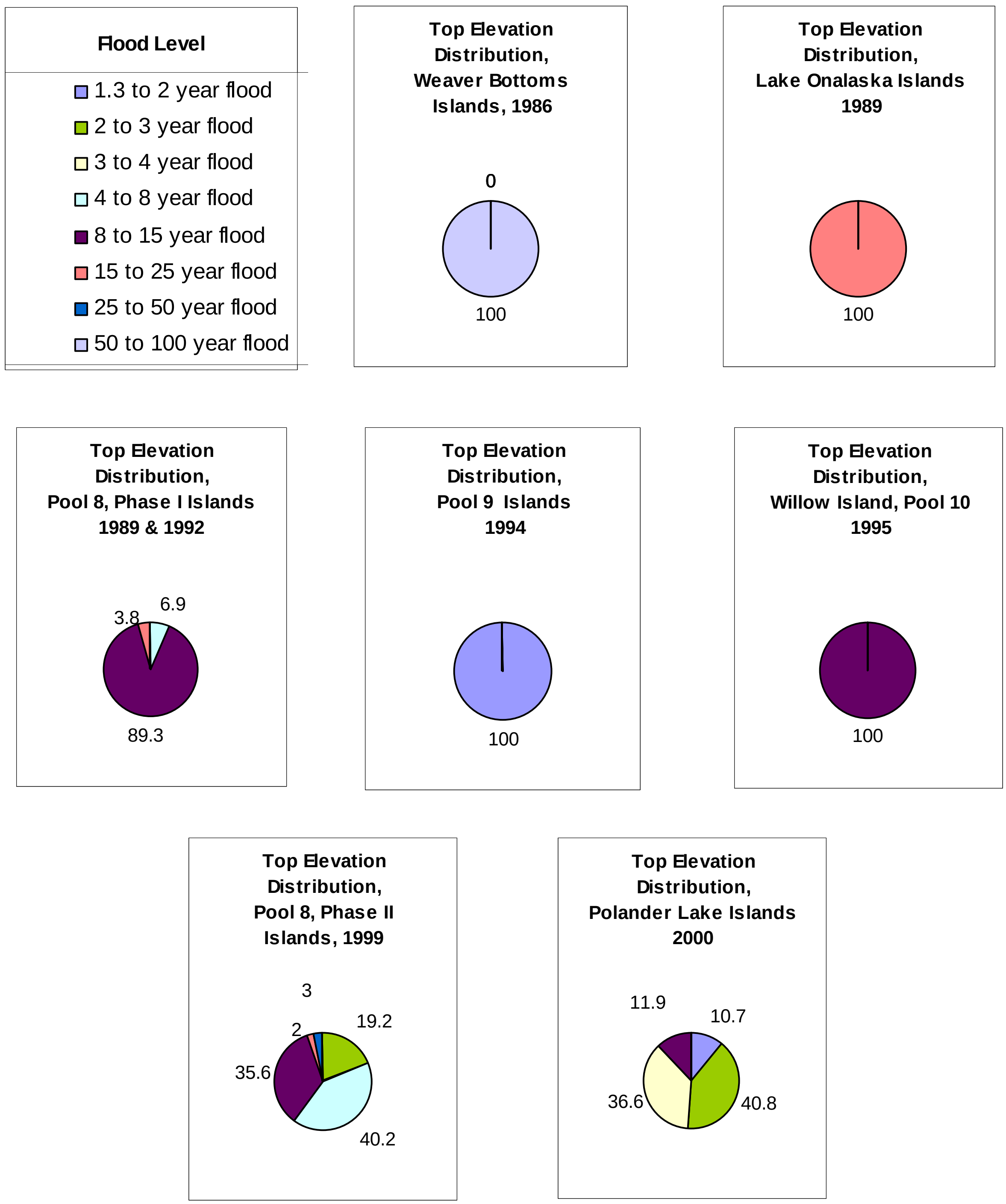


Figure 9.2. Distribution of Top Elevations Based on Flood Frequency for Constructed Island Projects

Islands are planted with or are naturally colonized by woody and herbaceous plants that stabilize the island and provide habitat (photograph 9.11). 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 that doesn't have vegetation due to wave action or ice action, and a littoral zone just below the water surface along the shoreline. Depending on a variety of factors, one or more of these zones may be absent. For instance, low elevation islands tend to be colonized with woody vegetation across the entire island, eliminating the grasses. Shorelines in sheltered areas may have woody vegetation right to the waters edge, eliminating the beach zone.

Photograph 9.11. Pool 5, Weaver Bottoms, Swan Island
Native prairie grasses were planted to provide nesting habitat and stabilize the top of the island.

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, 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 six different cross sections, six different tree and shrub planting schemes, and four different grass/forb planting schemes.

9.3.2 Vegetation and Topsoil. The top, side slopes, and a portion of the berm are capped with topsoil and planted with vegetation. Topsoil (which is labeled as fine material in figure 2) has cohesive properties, which resists erosive forces and provides substrate for vegetation. Vegetation reduces erosive forces before they cause erosion on the islands and provides habitat. Habitat benefits include nesting cover, food, and shelter associated with prairie grass communities. In 1993 and 2001 recently constructed islands with little or no vegetation 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. To maintain sandy substrate for turtle nesting, small sections of the Pool 18,Phase II Islands were constructed at a higher elevation and did not have topsoil placed on them. Several of these turtle nesting sections were severely eroded when they were overtopped by 1 to 2 feet of water during the 2001 flood, which was an 80-year flood event). Photograph 9.12 shows open water where there once was a sand section. 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 wouldn't get any larger. 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.

Photograph 9.12. Pool 8, Phase II, Slingshot Island

Islands constructed prior to 1990 in the northern half of the UMR, consisted of a sand core with a layer of topsoil spread over the sand. Boomerang Island, constructed in 1992, had a sand base that was one to two feet above the average water surface. The higher portion of the island consisted of up to a 4-foot layer of sediment with at least 50-percent fines. The Pool 8, Phase II Islands consisted of a sand base, with a 1 to 3 foot thick upper layer of random fill that was required to have more then 5-percent fines, capped by a 12" layer of select fines that had at least 40-percent fine sediments in it. The Polander Lake Islands were designed in a similar fashion with a sand base, topped by a layer of fill with no requirements on the fines, which in turn was capped by a 12" layer of material with a fines content of between 40 and 70 percent. Anfang and Wege (2000) concluded that there should be an upper limit to the percent fines contained in the topsoil, because material with too much fines tends to harden and become impermeable to rain infiltration. Therefore, the specification of 40 to 70-percent used at Polander Lake probably represents the standard as of this date. 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.

Table 9.4 provides information on the thickness and gradation of the topsoil and random fill layers on islands. One foot of topsoil has become the standard thickness to assure adequate coverage, good plant growth, and island stability.

Anfang and Wege measured the percent fine sediments in the topsoil of various islands and found: 27 and 32 % on Swan and Mallard Island in Pool 5, 37, 38, and 51 % on Broken Gun, Cormorant, and Arrowhead Islands in Pool 7, and 42 and 36 % 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).

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 (photograph 9.13). 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. The people in the photograph are walking on the berm on the sheltered side of the island.

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. Some of their recommendations are summarized in habitat parameter 4 later in this report. 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 9.4. Topsoil and Random Fill Thickness and Gradation

Project	Island Length (feet)	Topsoil Thickness (inches) and Minimum Percent Fines	Random Fill Thickness (inches) and Minimum Percent Fines	Year Constructed
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
Willow Island	3700	6		1995
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

Photograph 9.13. Polander Lake Islands

One of the primary purposes 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.

9.3.3 Shoreline Stabilization. A shoreline stabilization plan that involves the use of vegetation, rock, logs, synthetic grids, or some combination of living and inert materials is needed for all projects. At the 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. Shoreline stabilization of islands includes riprap (photograph 9.14), biotechnical methods (photographs 9.15 and 9.16) and vegetative stabilization (photograph 9.17).

Photograph 9.14. Lake Onalaska - Riprap and Geotextile Filter Placed on Sand

Photograph 9.15. Pool 8, Phase II, Boomerang Island - Biotechnical Stabilization with Groins and Willows

Photograph 9.16. Weaver Bottoms, Swan Island -
Biotechnical Stabilization with Fiber Rolls, Sand Bags and Willow Mats

Photograph 9.17. Pool 8, Phase II, Boomerang Island
Vegetative stabilization was used on over 60% of the shorelines on Boomerang Island.

A description of these techniques is given in table 9.5. In this document, the use of groins, vanes, and offshore mounds along sand berms that are planted with willows is considered biotechnical stabilization.

Table 9.5. Description of Shoreline Stabilization Techniques Used on Island Project

Riprap. Riprap increases the shear strength of the shoreline so that erosive forces do not displace shoreline substrate. The thickness and size of the riprap varies depending on the magnitude of the erosive force. Riprap can be designed with a high degree of precision, thus its performance and cost can be predicted more reliably than many other methods. Stone conforms readily to irregularities in the bank, whether they are due to poor site preparation, subsequent scour, or settlement and loss of sub-grade material.

Biotechnical Methods. Biotechnical methods use a combination of live vegetation and structural material to strengthen the shoreline or reduce the erosive forces that act on the shoreline. Live vegetation consists of woody vegetation while structural material includes rock or log groins, vanes, or mounds, and a sand berm. The function of each of these features is as follows:

Feature	Function
Groins	Contain littoral drift (i.e. the transport of sand along a shoreline due to wave action) of berm material to area between two groins. This results in a scalloped shoreline shape, which is the shoreline adjustment to the prevailing winds.
Vanes	Redirect river currents away from the shoreline. Erosive secondary currents are moved away from the toe of the bank.
Off-Shore Mounds	Reduce erosive forces due to wave action, river currents, or ice action
Sand Berm	Function 1 - Reduce erosive forces on main part of island at low flows Function 2 - Provide sand for beach formation Function 3 - Provide substrate for woody vegetation growth Function 4 - Provide habitat and elevation diversity Function 5 - Increases slope stability of main island cross section.
Woody Vegetation (Willows)	Function 1 - Reduce erosive forces on the island due to wave action, river currents, or ice action during floods. Function 2 – Provide floodplain habitat. Function 3 – Increase the downwind sheltered zone created by the island. Function 4 – Provide a visual barrier between areas that typically get human

In most island designs, near-shore berms are constructed along either side of the island (Figure 2). Near-shore berms eliminate or reduce erosive forces so that erosion of the main section of the island is prevented for both low water and high water conditions. During low water conditions, near-shore berms provide a direct barrier between erosive forces and the main portion of the island. During high water conditions, the woody vegetation that grows on near-shore berms reduces erosive forces on the island main section.

Vegetative Stabilization. Vegetative stabilization can be used along shorelines where offshore velocities are less than 3 ft/sec, wind fetch is less than 1/2 mile, ice action and boat wakes are minimal, or where offshore conditions (depth or vegetation) reduce erosive forces. This is the same as the biotechnical designs discussed above except that groins, vanes, or mounds are not needed to stabilize the outer edge of the berm.

Other Biotechnical Methods. A number of other biotechnical methods have been used to a limited extent on shorelines to reduce erosion. These include the use of synthetic reinforcement grids, willow mats, and fiber or willow rolls for toe protection.

Table 9.6 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 rock gradation used for riprap and groins is given in table 9.7. The standard gradation, which is similar to ASTM R-60, was established based on ease of obtaining it from quarries and the requirements for wave action, which is the primary erosive force affecting islands. The large gradation has been used on several projects where wind fetch exceeded 2 miles, or where ice action was expected to be a problem. It has also been used to discourage people from moving rocks. The cobble gradation was used to repair a couple of sections of the Pool 8, Phase II islands that were damaged during the 2001 flood. These sections were not exposed to significant wave action and field reconnaissance indicated that while sand size material had been eroded during overtopping, gravel-size material and larger was stable, so a cobble gradation was used.

9.3.4 Cost. The cost of the three most recent island projects, Pool 8, Phase I and II, and Polander Lake, is shown in table 9.8 .

The rock sills constructed as part of the Pool 8, Phase II project were very expensive. 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 a nearly a factor of two. The inclusion of this the 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.

Material costs for earth islands are given in table 9.9. 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 9.6. Shoreline Stabilization Length and Percent of Total Length Used on Island Projects

Island	Total Shoreline Length (feet)	Riprap Stabilization Length		Biotechnical Stabilization Length		Vegetative Stabilization Length		Year Constructed
		feet	percent	feet	percent	feet	percent	
Weaver Bottoms	17400	2180	13%	5670	33%	9550	55%	1986
Lake Onalaska	9540	7370	77%	1280	13%	890	9%	1989
Pool 8, Phase I, Stage 1, Horseshoe	6900	600	9%	0	0%	6300	91%	1989
Pool 8, Phase I, Stage 2, Boomerang	17330	1885	11%	4600	27%	10845	63%	1992
Pool 8, Phase I, Stage 2, Grassy	2600	780	30%	1100	42%	720	28%	1992
Willow Island	3700	900	24%	1700	46%	1100	30%	1995
Pool 8, Phase II, Eagle Island	5660	460	8%	3450	61%	1750	31%	1999
Pool 8, Phase II, Slingshot I	10800	600	6%	7520	70%	2680	25%	1999
Pool 8, Phase II, Interior Islands	4700	800	17%	3900	83%	0	0%	1999
Polander Lake, Stage 2 Barrier Islands	10,000	1000	10%	4600	46%	4400	44%	2000
Polander Lake, Stage 2 Interior Islands	4210	120	3%	0	0%	4090	97%	2000
Average			19%		38%		43%	

Table 9.7. Rock Gradations Used on HREP Projects

	Standard Gradation	Large Gradation	Cobbles
W100 Range (lbs)	300 to 100	630 to 200	9 to 5
W50 Range (lbs)	120 to 40	170 to 70	4 to 2.5
W15 Range (lbs)	25 to 8	60 to 15	2 to 1

Table 9.8. Costs of the Pool 8, Phase I and II and Polander Lake Island Projects

Project	Year Constructed	Feature	Length (feet)	Cost (dollars)	Cost/Foot
Pool 8, Phase I, Stage 2	1992	Earth Islands	9,600	$1,456,000	$151
		Earth Islands	10,600	$1,755,000	$165
		Rock Sills	2,500	$ 722,000	$288
		Seed Islands	1,280	$ 169,000	$132
Pool 8, Phase II	1999	Total Cost		$2,646,000	
Polander Lake, Stage 2	2000	Earth Islands	9,200	$1,897,000	$206

Table 9.9. 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, etc	Mob/ Demob	Geo-textile	Loafing Structure
Pool 8, Phase I, Stage 2	1,456	$5.46/yd[2] 855 59%	$6.95/yd[2] 389 27%	N/A	$14.50/ton 140 10%	$1250/ac 22 1.5%	20 1.1%	*	2.50/yd[3] 18 1.2%	N/A
Pool 8, Phase II	1,707	$2.88/yd[2] 501 29 %	$4.70/yd[2] 238 14 %	N/A	$33/ton 550 32%	$2491/ac 47 3%	148 9%	186 11%	3.85/yd[3] 37 2%	N/A
Polander Lake, Stage 2	1,819	$2.90/yd[2] 518 28%	$17.50/yd[2] 538 30%	$2.55/yd[2] 93 5%	$35/ton 372 20%	$1990/ac 31 2%	53 3%	177 10%	3.40/yd[3] 14 1%	14 1%
Peoria Lake				$2.00/yd[2]						
Pool 11 Islands				$10.90/yd[2]						

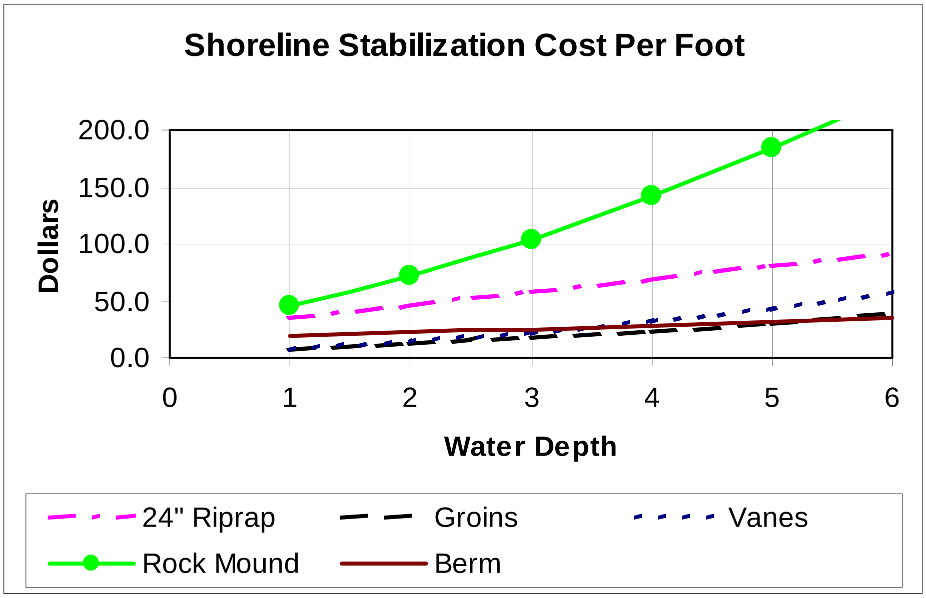
[1] In each box the top number is the unit costs, the middle number is the total dollar amount paid the contractor for each material (in thousands of dollars), and the bottom number is percentage of the total earth island cost paid for each type of material. Dollar amounts are based on the base contract 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] cubic yards

[3] square yards

* 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.

Shoreline stabilization costs include earth fill (granular and fines) for the berm, rock, and the cost of willow plantings. Figure 9.3 shows estimated costs for constructing various types of shoreline stabilization in water depths of 1 to 6 feet. The berm cost must be added to the cost of the various types of rock structures. Groins and vanes are the cheapest stabilization option, regardless of water depth. Rock mounds are the most expensive option in all cases. The cost for planting willows was assumed to be $2 per linear foot based on the bid prices for the Pool 8 Phase II and Polander Lake projects (table 9.10).



Assumptions
1. Rock cost equals $35/ton or $49 cubic yard in place
2. Sand cost equals $3/cubic yard
3. Fines cost equals $12/cubic yard
4. Height of rock structures above average water surface is 2 feet.
5. Side slope of 24 inch rock fill equals 1V:3H
6. Side slope of groins, vanes, and rock mound equals 1V:1.5H
7. Top width of groins, vanes, and rock mound equals 4’
8. Groin and vane length is 30 feet, and spacing is 180 and 90 feet respectively
9. Berm width equals 30 feet, half the berm (15 feet) is covered with topsoil to a depth of 1 foot, and willow cost is $2 per foot for 2 rows of willows.

Figure 9.3. Shoreline Stabilization Costs Per Foot of Shoreline

Table 9.10. Cost of Willow Plantings on Two Island Projects

Project	Bid Price	Shoreline Length (f)	Cost Per Foot
Pool 8, Phase II	$29,000	19,300	$1.50
Polander Lake	$8,400	3,750	$2.24

9.4 Lessons Learned

Many lessons have been learned during the design, construction, and maintenance of island projects. Several major floods have occurred during the 20 years that the islands have been in existence, providing valuable information on project durability, maintenance requirements, and rehabilitation methods. Lessons learned regarding biological response have been developed by monitoring the change in abundance of aquatic vegetation, fish, and wildlife. 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. Tables 9.11 through 9.17 list lessons learned from previous projects. There are seven different tables—six that cover different design categories and a separate table for constructability. The numbering system for the lessons learned is illustrated below. The six design categories are designated by the numbers 1 through 6, and the 14 projects are designated by the letters A through M.

1.B.3

Design Category

1. Layout
2. elevation
3. width
4. side slope
5. topsoil & vegetation
6. shoreline stabilization

Project

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 Islands, Pool 5
L. Peoria Lake, Illinois River
M. Bertom McCartney
N. Pool 11 Islands

Lesson Learned

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 southern most bay of Mallard Island. 1.A.2 Islands in deep water have a 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.
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: Macrophytes (if water depths are three feet or less) Fish for use as a nursery area Finger Nail Clams Diving ducks that fed on the Finger Nail clams (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 Island, 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. The vegetation response along the deeper eastern half of the island was not as good. 1.B.6 Islands in deep water have a 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* for a description the beach formation process.

Table 9.11. Lessons Learned, Design Category 1- Island Layout

Project	Year Constructed	Lessons Learned
Pool 8, Phase I, Stage I Horseshoe Island	1989	1.C.1 The shallow off-shore water depths along portions of this island eliminated the need for rock protection. During the hydraulic placement of dredge material for this island, the resulting island slope was so flat that it formed a berm and no further shaping or protection was required. 1.C.2 Placement of islands a distance back from the navigation channel (100 to 300 feet) 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 8, Phase I, Stage II Boomerang	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 should do 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 Islands do affect sediment transport within the floodplain. Shortly after construction, deposition was observed along the north south leg of Boomerang Island and in the vicinity of Heron and Trapping islands downstream of the project area. The deposition occurring in the Heron and Trapping islands area was the catalyst leading 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 conceptual 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 feet deep) bounded by these islands. These islands were laid out so that wind fetch from the northwest and southeast was reduced to less than 4,000 feet. 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 an aesthetic appearance 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-percent 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 feet 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 feet 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 feet. The interior islands were positioned to protect the shallow areas from southerly winds, reducing wind fetch from the south to less than 4,000 feet. 1.H.4 Two-dimensional hydrodynamic 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 November to March time period, which would keep elevations high. The elevation chosen limited November to March overtopping to 1 year in 10. SO far this seems to have been a reasonable design criteria. 1.H.6 The affects of ice cover on velocity was modeled and resulted in a change to the cross-section of the notch in upper rock sill. To account for ice affects, modeled velocities were adjusted based on the decrease in conveyance area that would occur from 2 feet of ice. WDNR monitoring indicates that the design goal of 50 cfs has been achieved.
Polander Lake	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, 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 interior islands were in the 2 1/2 - 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 Island 4, which was in deeper water, eroded rapidly after construction due to wind-driven wave action. This was a tapered section of the island and the narrower width increased concern that a breach might form across the island.

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 & 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 feet over the average water surface. 2.A.2 Low elevation berms (less than 2 feet above average 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 elevation of these islands (6 feet over the average water surface) combined with periodic burning has maintained native prairie grasses on the islands delaying the conversion to woody vegetation. USFWS personnel (Nissen, pers. com.) feel that the higher elevation is the primary factor because the fuel load on these islands is insufficient to create a hot enough fire to kill the woody vegetation. 2.B.2 The higher elevation berms (approximately 3 feet over the average water surface) delayed the 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 Is	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 feet above the average water surface elevation 2.C.2 Significant portions of the backwater side of Horseshoe Island were less than 2 feet over the average water surface. Dense woody vegetation growth occurred on these areas right down to the pool level.
Pool 8, Phase I Stage II Boomerang	1992	2.D.1 Islands less than 5 feet above the average water surface elevation are more likely to convert to herbaceous and woody vegetation. Boomerang Island was constructed to an elevation of approximately 4.5 feet above the average water surface elevation. This island rapidly converted 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-year flood elevation). During the 1993 flood (approximately a 15-year 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 feet of water. 2.D.3 The berms on Boomerang Island sloped from 2 feet over the average water surface where the berm attached to the main part of the island, to 0.5 feet over the average 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 feet, and finally to 634.8 for the lowest 5900 feet. This may have been one of the factors that has 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.

Table 9.12. Lessons Learned, Design Category 2 - Island Elevation

Project	Year Constructed	Lessons Learned
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 several times and show minimal damage.
Pool 8, Phase II	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 years 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 downstream end is the first section of earth island that is overtopped, then the next section, 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 were overtopped during the 2001 flood and 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 floodplain that normally break up wind fetch are now submerged. In addition, current velocities reach a maximum in floodplains and any feature that redirects flow (like an island), causes currents to accelerate resulting in erosion at the edge of the feature. The features on these islands 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 feet higher than the highest island section). The 2001 flood had a long crest with twin peaks that resulted 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 one of them completely scoured out to below pool elevations (629 to 630). The typical sections of islands that varied in elevation from 633 to 635 were stable. 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.
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 per square foot.

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 island due to rainfall runoff. This was not a major problem, however 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 feet specified in the design. The deep water (greater than 3 foot 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 Island	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 in the shallow backwater creating a large footprint over 150’ wide in some cases.
Pool 8, Phase I Stage II Boomerang	1992	3.D.1 Berm width on these islands was 30 feet in most cases. This was adequate over 95-percent 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 Island the berm width was reduced to 20 feet. These reaches either had shallow offshore water depths (less than 2 feet 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 but provide little terrestrial habitat and are aesthetically challenged. 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, but have been criticized for their lack of terrestrial habitat and aesthetics.
Willow Island	1995	3.G.1 The majority of this island was stable during the 1997 and 2001 flood even though its top width was only 10’. However, a couple of small breaches did form in 1997, indicating that 10’ may be approaching the lower limit for top width.

Table 9.13. Lessons Learned, Design Category 3 - Island Width

Project	Year Constructed	Lesson Learned
Pool 8, Phase II	1999	3.H.1 Berm width on these islands was 30 feet in most cases. This was adequate over 95-percent 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 at this project were set at 13' in case a scour hole developed downstream of the rock sill. The thought was that if scour started under-mining the downstream toe, the sill would be wide enough for some self-healing to occur. However, field reconnaissance indicates that scour has not occurred at these rock sills (Photograph H.15, appendix A). The rock sill top width probably could have been 10' and perhaps even 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 even though their top widths were only 20'. However, a couple of breaches did form, and small areas of erosion were observed, indicating that 20' may be approaching the lower limit for top width. 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 feet in width.
Spring Lake Islands	2005	3.K.1 The contractor found it difficult to maneuver equipment on island 1 because of its narrow width. Island 1 was designed with a top width of 20 feet, to reduce the size of the island footprint. A 40 foot width would have resulted in better maneuverability. 3.K.2 The downstream end of Island 4, which was in deeper water, eroded rapidly after construction due to wind-driven wave action. This was a tapered section of the island and the narrower width increased concern that a breach might form across the island. If this section had been wider, this concern wouldn't have been so great.

Table 9.14. Lessons Learned, Design Category 4 - Side Slope

Project	Year Constructed	Lessons 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 feet or more.
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 Island	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. 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 quickly reshaped the berms, which had been constructed at a 1V:20H slope. 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.
Swan Lake Illinois River	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 - Topsoil and Vegetation

Project	Year Constructed	Lessons 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-feet above the average water surface 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-feet above the water surface 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 Island	1989	5.C.1 High islands delay the conversion from grassy to woody vegetation. The west leg of Horseshoe Island is 5 to 6 feet above the average water surface 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.
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 years 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 average gradation of topsoil on this island, based on 5 samples, was as follows: 61-percent clay, 27-percent silt, and 12-percent 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 years of project construction, however it was greatly reduced from year 5 to 10 due to rodents girdling and killing the trees.

Table 9.15. Lessons Learned, Design Category 5 - Topsoil and Vegetation

Project	Year Constructed	Lessons Learned
Pool 8, Phase II	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.
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 years 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 was 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.
Swan Lake Illinois River	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 River	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.

Table 9.16. Lessons Learned, Design Category 6 - Shoreline Stabilization

Project	Year Constructed	Lessons 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 years 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. 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 feet, eroded very little. 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 feet over the average water surface elevation. This had been reduced to 1 foot or less within about 5 years. This was not a problem since rock mound elevations only need to be near the average 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 year. 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 feet) 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 years even though grassy vegetation had established itself on the berm.

Table 9.16. Lessons Learned, Design Category 6 - Shoreline Stabilization

Project	Year Constructed	Lessons Learned
Pool 8, Phase I Stage I Horseshoe Is	1989	6.C.1 Delaying the application of bank stabilization by one year or more may allow refinement of the overall stabilization plan, resulting in more vegetative stabilization and decreased use of rock. Less than 10-percent of this shoreline was stabilized with riprap even though over 50-percent 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 feet 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 Placing 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	Lessons Learned
Pool 8, Phase I Stage II Boomerang	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 years willow growth on the berm spreads from the water line to almost the top of the island, providing a 20 to 30 foot swath of willows. 6.D.2 Groins are an effective low cost means of stabilizing shorelines if wind driven wave action is the primary erosive force. Groins were not used as a means of shoreline protection until Boomerang Island was constructed in 1992. This method of protecting shorelines was so successful that groins 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-percent 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 feet 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 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 Boomerang Island. The water was slightly deeper here and there was not as much vegetative stabilization as the east-west leg. 6.D.7 The 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 Is	1994	6.E.1 Islands constructed of rock are stable; however some settling may occur.
Pool 8 Phase II	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 feet.
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 Is	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.

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 affect 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 feet. 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 Is**	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 year before they were placed on the island. 7.C.3 Heavy construction equipment can operate in fine sediments as thick as 2 feet without major problems. The fine sediments on Horseshoe Island were up to 2 feet 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.
Pool 8 **Phase I** **Stage II** **Boomerang Is**	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 feet, 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-foot section that included a large amount of fines. A sand base had been placed along this reach the year before. This created a construction base off of 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.

Table 9.17. Lessons Learned, Constructability

Project	Year Constructed	Lesson Learned
Pool 8, Phase II	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. 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 feet without major problems. The fine sediments on the phase II islands were up to 3 feet 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 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 base to form temporary cells for the containment and 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 based on the fines cost comparison in Table 9.
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 River	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 River	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.

9.5 Design Criteria

Tables 9.18 through 9.23 list criteria that have been developed for island design. The criteria is listed in six tables that cover six different design categories:

1. Island Layout
2. Elevation
3. Width
4. Side Slope
5. Topsoil & Vegetation
6. Shoreline Stabilization.

Each of the tables is subdivided into four design disciplines:

- Geomorphology
- Engineering
- Constructability
- Habitat

References linking the design criteria to the Physical Attribute (Appendix A), Habitat Parameter (Appendix B), Engineering Consideration (Appendix C), or lesson learned that the criteria is based on is provided. These criteria should be used as a guide for designing island projects; however, each project has its own unique characteristics that will require adjustments. The creative talents of design teams will continue to produce new innovations and new lessons learned.

Table 9.18. Design Criteria, Design Category 1 - Island Layout

Design Discipline	Design Criteria
Geomorphology	1.a Restore a riverine flow regime by rebuilding natural levees along channels. For below bankfull flow conditions, the majority of the flow conveyance should be in channels. The ratio of floodplain to channel discharge during floods should be less than 1.0. Reduce wind fetch to less than 4000 feet for average water depths of 3 feet. *Reference: Physical Attributes 1 – 5, 7; Engineering Consideration 4* 1.b Position islands to shelter adjacent shallow areas and reduce sediment resuspension. *Reference: Physical Attributes 2, 7; Engineering Consideration 4* 1.c Identify erosion and deposition zones. Position islands to increase or maintain the magnitude of erosion and deposition in their respective zones to maintain or increase bathymetric diversity. A state of dynamic equilibrium is desired where annual episodes of erosion and deposition balance each other. *Reference: Physical Attributes 1, 3, 4, 5, 7; Lessons Learned 1.B.1; Engineering Considerations 2,4* 1.d Spacing between islands and the resulting wind fetch should account for the water depth of the area that is sheltered by the island. 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) 1 2 3 4 Fetch (feet) 1500 3500 6000 9000 *Reference: Lessons Learned 1.H.3 Engineering Consideration 4*
Engineering	1.e Locate islands in shallow water to reduce costs and erosion potential. *Reference: Lessons Learned 1.A.2, 1.B.6, 1.C.1, 1.D.2, 1.K.1* 1f. Position islands in locations where islands existed but have eroded away to minimize displacement of existing substrate (i.e. mud-wave formation) and long-term settling. 1.g Incorporate existing island remnants into new island to reduce material quantities, shoreline erosion, and substrate displacement, and for aesthetics. *Reference: Lessons Learned 1.D.1, 1.H.1* 1.h Position perpendicular to flow and dominant wind fetch. *Reference: Lessons Learned 1.B.1, 1.B.2, 1.E.1* 1.i Initiate two-dimensional modeling early in the planning process as possible, so that results from the model can effectively be used to optimize island layout. Once an island layout is agreed to during the planning process, it is difficult to make substantive changes during later design stages because the layout decided on during planning reflects compromises by the interagency team concerning conflicting habitat goals and objectives, costs, and engineering requirements. *Reference: Lessons Learned 1.H.4*

Table 9.18. Design Criteria, Design Category 1 - Island Layout

<table>
<tr><th>Design Discipline</th><th>Design Criteria</th></tr>
<tr><td>Constructability</td><td>1.j Minimize access channel dredging, by positioning some reaches of islands close to deep water (5 feet in depth). Reference: Lessons Learned 1.D.3</td></tr>
<tr><td>Habitat</td><td>
1.k Maximize habitat area sheltered by island. Islands should be positioned to shelter the maximum amount of floodplain habitat. This includes areas that are deep (greater than 4 feet) for overwintering fish habitat and shallow (less than 3 feet) where aquatic vegetation is likely to grow. Reference: Lessons Learned 1.A.1, 1.B.1, 1.B.2, 1.B.3, 1.E.2, 1.H.3; Habitat Parameters 1,2,3; Engineering Consideration 4
1.l The following conditions should be met with regards to fish habitat. This criteria is based on research and input from State and Federal fisheries biologists.
<table>
<tr><th>Species</th><th>Velocity
(fps)</th><th>Temperature
(° C)</th><th>D.O.
(mg/L)</th><th>Depth
(feet)</th><th>Substrate</th></tr>
<tr><td>Centrarchids, winter</td><td>< .01</td><td>2-4</td><td>> 3</td><td>> 4</td><td></td></tr>
<tr><td>Centrarchids, summer</td><td></td><td></td><td>> 5</td><td></td><td></td></tr>
<tr><td>Centrarchids, spawning</td><td>< .016</td><td></td><td>> 5</td><td></td><td></td></tr>
<tr><td>Centrarchids, nursery</td><td>< .016</td><td></td><td>> 5</td><td></td><td></td></tr>
<tr><td>Lake Sturgeon</td><td>.328 - 1.31</td><td></td><td></td><td>3 – 13</td><td>silt-sand</td></tr>
<tr><td>Shovelnose Sturgeon</td><td>.65 - 1.48</td><td></td><td></td><td>13 – 25</td><td>sand</td></tr>
<tr><td>Paddlefish</td><td>< .16</td><td></td><td></td><td>13 – 25</td><td></td></tr>
</table>
Lake Sturgeon and Shovelnose Sturgeon prefer a transition zone between high velocity and low velocity, apparently adjusting their position to the most favorable conditions.
Reference: Lessons Learned 1.B.3, 1.H.2; Habitat Parameter 1
1.m Aquatic vegetation growth following island construction is a function of wind fetch, river currents, water depths, and substrate. Habitat Parameter 3 provides information on this. Reference: Lessons Learned 1.A.1, 1.B.3, 1.B.5, 1.E.2, 1.H.3; Habitat Parameter 3; Engineering Consideration 4
1.n Create multiple habitat areas with visual barriers (i.e. island with vegetation) for waterfowl resting. Reference: Habitat Parameter 2
1.o Position islands to create a littoral/riparian zone that provides loafing structure, shelter, and food along channel borders and in backwaters. In backwaters, this is to take advantage of the extremely sheltered zone immediately downwind of an island which equals 10 times the island and tree height. Reference: Physical Attribute 1; Habitat Parameter 5; Engineering Consideration 4
</td></tr>
</table>

Table 9.19. Design Criteria, Design Category 2 - Island Elevation

Design Discipline	Design Criteria
Geomorphology	2.a Islands should be constructed with a top elevation near the bankfull flood elevation to create hydrodynamic and fluvial conditions similar to those that existed for natural conditions. The bankfull flood elevation has a recurrence interval of 1.5 to 3 years. Since floodplain resistance is lower in the downstream section of the pools, an elevation slightly higher than bankfull might be needed to maintain a ratio of floodplain to channel discharge during floods less than 1, and more closely represent natural conditions. *Reference: Physical Attribute 5, 7; Engineering Consideration 3*
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. That rate at which the island is stepped down should be greater than the water surface slope, to ensure this downstream to upstream progression. *Reference: Lessons Learned 2.D.4,2.H.1* 2.c Rock islands or sills may replace portions of earth islands to provide floodplain flow for more frequent floods. These features should have a lower elevation than earth islands so flow first occurs over the rock reducing hydraulic forces across the earth islands during later stages of the flood. *Reference: Physical Attribute 5,7; Lessons Learned 2.E.1, 2.H.1; Engineering Considerations 2, 3* 2.d Earth berms, which are constructed on either side of the island for stabilization, should be 1 to 2 feet or above the average water surface elevation to provide optimum conditions for vegetation growth. Usually 2 feet is recommended so that there is enough sand in the berm for beach building, however a 1 foot high berm is better for Willow growth. *Reference: 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 to mimic natural island morphology. 2.f In many reaches of the Upper Mississippi River, the sediment transport load is supply limited, resulting in relatively low sediment concentrations during floods. This means that sediment concentrations peak near the bankfull discharge and remain steady or decrease from this point on. By choosing low top elevations, the clean water that often occurs at higher discharge is conveyed over the island and through the project area, potentially scouring accumulated sediments. *Reference: Physical Attribute 5, 7; Engineering Consideration 2* 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*

Table 9.19. Design Criteria, Design Category 2 - Island Elevation

Design Discipline	Design Criteria
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 foot 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 feet can be considered. Reference: *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*
Habitat	2.k Design elevation should provide desired vegetation. Islands higher than 5 feet over the average water surface tend to retain their grass cover, while islands lower than 5 feet tend to convert over to herbaceous and woody vegetation. Other factors such as topsoil depth, also affect vegetation communities. *Reference: Physical Attribute 9, 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* 2.l Vary island elevations from around a 2-year flood elevation to a 10-year flood elevation to provide topographic and subsequent vegetation diversity. *Reference: Physical Attribute 9, 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* 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). *Reference: Habitat Parameter 1* 2.n If island function includes nesting, the top elevation should exceed the level of the 10-year flood event. *Reference: Habitat Parameter 6* 2.o On extremely sheltered shorelines, sand flats or mudflats can be constructed. The elevations of these features should be set 0.2 to 0.3 feet 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 0.3 feet. *Reference: Habitat Parameter 5*

Table 9.20. Design Criteria, Design Category 3 - 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 floodplain to channel discharge ratio less than 1.0 during floods. *Reference: Physical Attribute 4, 5, 7*
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. The range of widths used on previous projects (70 to 200 foot base width, 10 to 100 foot top width) has resulted in stable islands in almost all cases. Minor erosion and breaches have formed on islands with top widths of 10 and 20 feet, however these were easily fixed. This suggests that island width can be at the lower end of the range given above, however, the headloss across the island must be considered. *Reference: Lessons Learned 3.G.1, 3.I.1; Engineering Consideration 5* 3.c Rock sill top widths should be set at 10' to allow equipment access and to minimize seepage. However if head differentials exceed 0.5 feet, widths may have to be increased. *Reference: Lessons Learned 3.H.2* 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 strip for vegetation growth. The standard berm width used on the latest projects is 40 feet, 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. *Reference: Lessons Learned 3.B.1, 3.D.1, 3.D.2, 3.H.1: Engineering Consideration 6* 3.e Islands in more erosive environments should have their overall width increased to decrease the chance of breaches forming during an overtopping width. *Reference: Lessons Learned 3.K.2*
Constructability	3.f 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. *Reference: Lessons Learned 3.C.1* 3.g Rock sill widths are usually set at 10' to allow equipment access over the top of the sill. However, this option is rarely used by contractors, so some flexibility to adjust rock sill width exists. 3.h The minimum working width for efficient equipment operation is 40 feet. *Reference: Lessons Learned 3.K.1*
Habitat	3.i Width may affect island function as a migratory corridor. A minimum top width of 50 feet should be used to create a forest interior for migrating birds.

Table 9.21. Design Criteria, Design Category 4 - Island Side Slopes

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. Berms should be constructed wide enough so that after the beach has formed (through erosion of the berm) there is enough berm width left to protect the island. *Reference: 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. *Reference: 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, side slopes should be 1V:4H or flatter. *Reference: 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). *Reference: Lessons Learned 4.D.2* 4.f A flatter side slope improves the constructability of islands that are constructed using fine sediments. *Reference: 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 bird habitat and create a barrier to nesting turtles. Side slopes are usually not based on habitat. *Reference: Lessons Learned 2.A.2, 2.C.2, 2.D.3, 4.D.1; Habitat Parameters 4, 5, 6*

Table 9.22. Design Criteria, Design Category 5 - Topsoil 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.
Engineering	5.b A topsoil thickness of 12 inches is recommended to provide adequate coverage throughout the island. *Reference: Lessons Learned 5.D.1, 5.D.2, 5.H.1, 5.I.1; Habitat Parameter 4* 5.c Topsoil should consist of at least 40-percent fines (i.e. 40-percent of material passes 200 sieve), but not more than 70-percent fines. Coarse material is needed for infiltration. Anfang and Wege found that sites with more than 35-percent fines had a higher percent cover than sites with lesser amounts. *Reference: Lessons Learned5.D.2; Habitat Parameter 4* 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 helps to stabilize islands during overtopping events. This is especially important since Anfang and Wege found that it may take several (three to six) growing seasons before vegetation reaches a desired/maximum density. *Reference: 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. *Reference: Habitat Parameter 4* 5.g The thickest layer of topsoil that has been placed with standard construction equipment is 4 feet - this is about the upper limit for constructability. *Reference: 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*
Habitat	5.i 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 other birds that use grass. The following table provides some guidance on topsoil thicknesses. Vegetation Type — Topsoil Thickness Shrubs , Trees & Herbaceous — 12" or greater Grasses — 6" to 12" *Reference: Lessons Learned 5.A.2, 5.B.2, 5.C.1, 5.D.2; Habitat Parameter 4, 6* 5.j 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. 5.k Consider techniques to discourage grazing of new plants during the first few years after construction. Reference: *Lessons Learned 5.J.1*

Table 9.23. Design Criteria, Design Category 6 - Island Shoreline Stabilization

Design Discipline	Design Criteria
Geomorphology	6.a Stabilize island shorelines when the combination of river currents, waves, or ice remove substrate from a reach of shoreline faster than it is transported in. *Reference: Physical Attribute 5* 6.b Rock or wood structures must be constructed along 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. *Reference: Lessons Learned 6.A.8, 6.B.3* 6.c Create dynamic shorelines with a transition from aquatic habitat to beach habitat to terrestrial vegetation. If the shoreline is completely stable, terrestrial vegetation will encroach into the beach zone. *Reference: Lesson Learned 6.D.1*
Hydraulic/ Sediment Engineering	6.d Use tables 4, 7, 9, 10, and figure 4; Engineering Consideration 1 (Appendix C), and the Shore Protection Manual 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. *Reference: Lessons Learned 6.A.1, 6.B.2, 6.C.2, 6.D.3; **Engineering Consideration 1*** - Extremely sheltered shorelines (those exposed to less than a 2000 foot wind fetch) should be stabilized with vegetation only. *Reference: Lessons Learned 6.A.4; Engineering Consideration 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. *Reference: Lessons Learned 6.A.7, 6.E.1* 6.e On shorelines where wave action is the dominant erosive force, biotechnical stabilization should be used. This involves construction of an earth berm, at an elevation 2 feet or less above the average water surface, where woody vegetation will grow. The berm must be wide enough so that even if woody vegetation density is not high, there is sufficient energy dissipation 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. Although berms as narrow as 20 feet have been used where minimal erosion was expected, 40 feet is the standard berm width. Structural measures such as groins or offshore mounds may be needed to minimize berm erosion. Rock groins are constructed perpendicular to the berm to prevent longshore transport of sand. Offshore rock mounds can be used instead of groins to add diversity to an island shoreline. Willows are planted near the back of the berm for stabilization purposes. *Reference: Lessons Learned 6.D.1, 6.D.2; Engineering Consideration 1* 6.f On shorelines where river currents are the dominant erosive force, the same design as described above in 6e. is used except that vanes are used instead of groins. Vanes are 30 to 50 feet long, have a 3 foot top width, 1V:1.5 H side slopes and are spaced 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 the bankfull elevation at the shoreline to 1 foot below the average water surface at the riverward end. *Reference: Engineering Consideration 1* 6.g A swath of woody plants at least 20 feet wide is needed to provide rigid stems and protect the shoreline during the spring flood season. *Reference: Lessons Learned 6.D.1, 6.D.3; Engineering Consideration 1* 6.h If ice action is severe, flatten rock slopes to 1V:4H or flatter. *Reference: Lessons Learned 6.B.1; Engineering Consideration 1*
Constructability	6.i Provide access to the site for trucks or barges hauling rock.
Habitat	6.j Create diverse shoreline habitat with littoral/riparian area that includes aquatic, beach, and terrestrial zones. 6.k Build sand flats and mud flats near islands in sheltered areas. 6.l Use larger stone size than required to provide better substrate for benthic organisms and fish. *Reference: Habitat Parameter 1* 6.m 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) *Reference: Habitat Parameter 2, 5; Engineering Consideration 7*

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