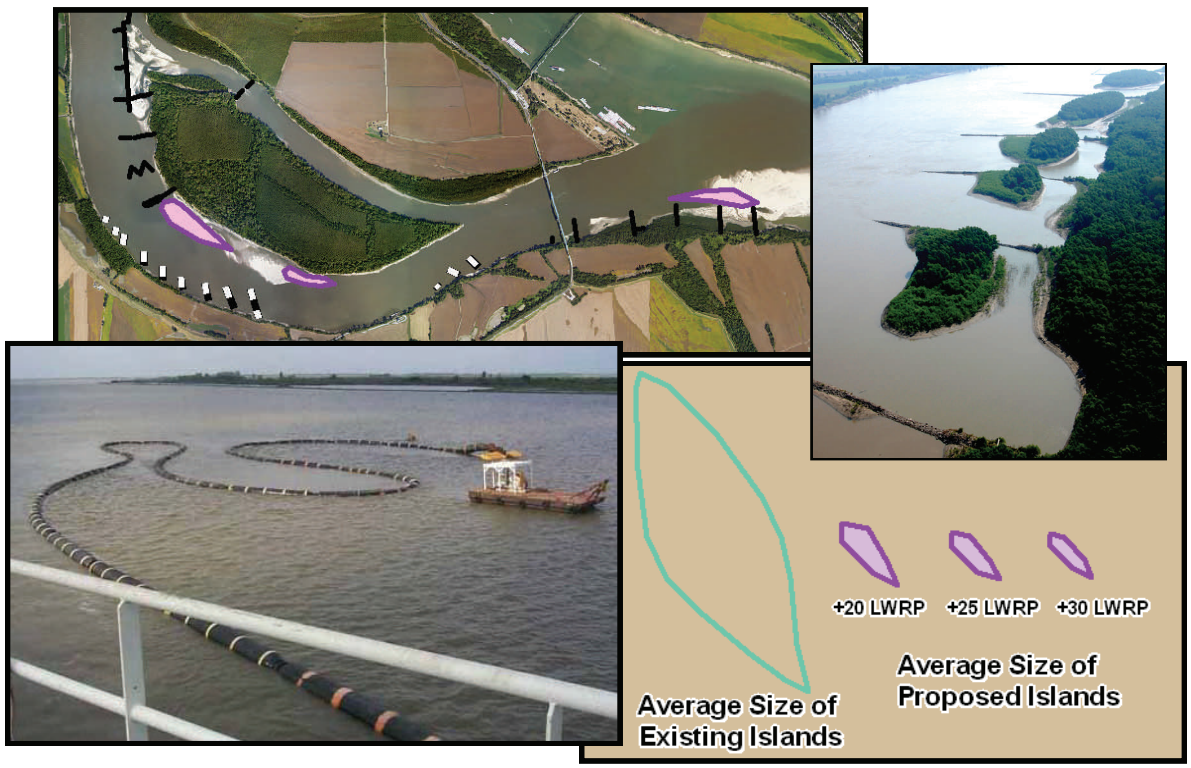
TECHNICAL REPORT M57

US Army Corps of Engineers
St. Louis District

# ENGINEERING CONSIDERATIONS FOR ISLAND AND SANDBAR CREATION USING FLEXIBLE FLOATING DREDGE DISPOSAL PIPE MIDDLE MISSISSIPPI RIVER, MILES 200.0 TO 0.0

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# Report M57

# Engineering Considerations for Island and Sandbar Creation Using Flexible Floating Dredge Disposal Pipe

# Middle Mississippi River, Miles 200.0 to 0.0

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## 1. Purpose

Standard dredging practice has traditionally limited the opportunity to use dredge material as sandbar or island habitat because of the physical limits of the rigid metal disposal pipe that is used. The rigid metal pipe only allows for a "side-cast" of dredge disposal parallel to the dredge cut in the main channel. The end result is a long, narrow disposal bar that is limited in size, elevation, location, and diversity to both aquatic and waterfowl species. A properly designed flexible floating dredge pipe operation, with or without the use of hydraulic structures and/or plantings, has the potential to create sandbars and islands in various shapes, sizes and elevations in the Middle Mississippi River.

This paper discusses past experience and uses of flexible floating dredge pipe and outlines engineering considerations for the creation of sandbars and islands using flexible floating dredge pipe on the Middle Mississippi River. US Army Corps of Engineers (USACE) personnel and partnering agencies have desired for a number of years to use dredge material to create sandbar and island habitat because of its potential to increase overall riverine habitat diversity, including the availability of wetted edge habitat, which provides forage and rearing habitat for a number of aquatic and terrestrial species.

## 2. Past Experience and Uses of Flexible Dredge Pipe in the Corps of Engineers

Flexible floating dredge pipe has been used to improve the efficiency of typical dredging operations as well as for marsh restoration and habitat creation. USACE Districts have utilized this technology since 2000. These include the New Orleans District (MVN) and the Mobile District (SAM). MVN has used the flexible dredge pipe for demonstration purposes only. SAM uses flexible dredge pipe in their standard dredging practices and for demonstration projects, replacing the older rigid steel pipe that was used for decades. Both of these districts have had positive independent feedback on the use of flexible floating dredge pipe.

### A. New Orleans District, MVN

Although the MVN currently is not using flexible floating dredge pipe in their day-to-day dredging operations, in 2002 and 2005 they did a demonstration project to verify the effectiveness of using a flexible-discharge dustpan dredge and flexible floating dredge pipe (Figure 1). The goal of the project was to illustrate the use of flexible floating dredge pipe for marsh construction and restoration. The second was to remove shoaling while studying the movement of sediment in the river. The intention was to achieve both goals while demonstrating safe navigation and dredging operations.

**Figure 1:** Flexible Floating Pipe (New Orleans)

For the first demonstration project performed by MVN, dredging activities took place during the spring of 2002. This demonstration project was located at the Head of Passes in the Mississippi River. During that time, it was determined that the only dustpan dredge with the required pumping capabilities was the *Beachbuilder* (Figure 2), owned by Weeks Marine, Inc. The flexible floating dredge pipe measured 30 inches in diameter and 1,410 feet (47 sections of 30 feet each) in length. Project operations lasted 11 days, but were terminated after various least tern (*Sterna antillarum*) and American avocet (*Recurvirostra americana*) nests containing eggs were found in the area.


**Figure 2:** *Beachbuilder* Dustpan Dredge

**Figure 3:** Least Tern Nest on Newly Placed Dredge Material for Wetland Restoration

During the operation, approximately 222,000 cu yd of material were dredged and placed in the wetland site. The *Beachbuilder* demonstrated safe navigation and dredging operations, and most requirements were met. The flexible floating pipe also worked well with no leaks or breaks. After all collected data was analyzed, the MVN and ERDC concluded that the demonstration project was successful. While the dredge material was beneficially used for wetlands restoration, it also created good nesting areas for the endangered least tern previously mentioned (Figure 3). Operational characteristics of this demonstration project indicate that this equipment could effectively work in other reaches of the Mississippi River.

**Figure 4:** Before and After Dredging Marshland Placement

### B. Mobile District, SAM

On July 19, 2011, St. Louis District (MVS) personnel traveled to Mobile, Alabama to learn how the flexible floating dredge pipe was used in the Mobile District of the Corps of Engineers. The purpose of this trip was to collect information about their experience using the pipe. This information provided necessary input into the potential use of flexible dredge pipe in MVS.

SAM has been using flexible floating dredge pipe for about ten years with positive results. The flexibility of the pipe allows the disposal of dredge material in various configurations that provides environmental benefits to dredge disposal areas. The flexible pipe is used for standard dredging disposal and sand dike creation, in both river and coastal projects.

With the dredge material, large disposal sites were created. Figure 5 shows a picture of a typical disposal site. The walls of the disposal sites were sand dikes. The dredge disposal sites in SAM were located away from the river. SAM uses a combination of HDPE (High Density Polyethylene pipe), flexible floating pipe, and rigid pipe for their dredging system. In the disposal location shown, about seven miles of flexible pipe transported the dredge material from the river bank to the dredge disposal location. Another 6,200 feet of flexible pipe was located on the river. Most of the flexible pipe used was HDPE pipe, since the majority of the pipe length was set on the ground with no need for floating capabilities. Figure 6 is a picture of the HDPE pipe. Sections of floating flexible pipe were joined to sections of rigid pipe supported by floaters in the water. Rigid pipe was used as stems for critical locations of dredging, such as booster pump locations. The flexible pipe gave the system needed mobility.

**Figure 5:** Dredge Disposal Site

**Figure 6:** HDPE Pipe

However, the additional mobility lead to reduced durability when compared to rigid steel pipe. The flexible floating pipe used by SAM was purchased from the oil industry and had about 10 years of use. The deterioration in the pipe was evident. Figure 7 is a picture of the deteriorated flexible floating pipe. Most of the damage to the pipe occurred during handling. Referring to past experiences with the flexible floating pipe, the SAM personnel had recommendations on how to handle the pipe. These recommendations included pipe lifting using nylon straps as opposed to steel cables. Also, the pipe should be lifted from the middle and not the edges to prevent the pipe from breaking due to high bending stresses. During the winter season when the pipe is not in use, it should be stored out of the water and covered to reduce weather related damage. Repairs to damaged pipe section should be made as needed.

**Figure 7:** Deteriorated Flexible Floating Pipe

Outlet pressures at the discharge end of the pipe were very large. To reduce the scouring potential of the dredge material coming out of the pipe, SAM employed various outlet attachments. The outlet attachment in use during the site visit was spoon shaped (Figure 8). Another attachment used in the past was a metal plate in front of the outlet that could be tilted in various directions.

**Figure 8:** Drawing of Spoon Connection (left), Spoon Connection (middle), and Spoon Connection in Use (right)

The contract dredge company working for SAM had their own spill barge with an apparatus that allowed them to aim the material disposal 15 degrees in any direction (left, right, up or down). Figure 9 shows the spill barge and the apparatus used to move the pipe in the desired direction.

**Figure 9:** Spill Barge used by SAM Contractors

## 3. Operational Design for Flexible Pipe in St. Louis District

The idea of using flexible dredge pipe for dredging in the St. Louis District started in 2005 when the concept was tested with HDPE pipe provided by the Memphis District. Figure 12 shows the HDPE pipe connected to the Dredge Potter. During the testing period, MVS discovered that the HDPE pipe sank once it was full of material. This made it difficult to manage and completely inefficient for the desired purpose of increased mobility. After this, the idea of using flexible “floating” dredge pipe for the creation of artificial islands and sandbars was introduced to the St. Louis District.

**Figure 12:** HDPE Pipe connected to Dredge Potter

The rubberized, flexible floating dredge pipe shown in Figure 13 was purchased and delivered in 2009. The total cost was $8,000,000. A total of 67 floating hoses and two 22.5 degree elbows were purchased. Each floating hose section had 39 feet of length, a 63 inch exterior diameter, and a 32 inch interior diameter. The pipe was made of layers of dense rubber (similar to tire material). It had a 1.57 inch wear lining with three colored wear indication layers. The layers show the interior wear of the hose and indicate when replacement is required. A technical manual on how to handle, assemble, and other important details was provided by *IHC Merwede BV*.

**Figure 13:** Flexible Floating Hose Section

For the use of the flexible floating dredge pipe, it was necessary to design and construct several elements. The Potter Crew developed the assembly method and transportation system of the hose. The crew also designed a towing configuration for passage through a 600 ft lock (Figure 14).

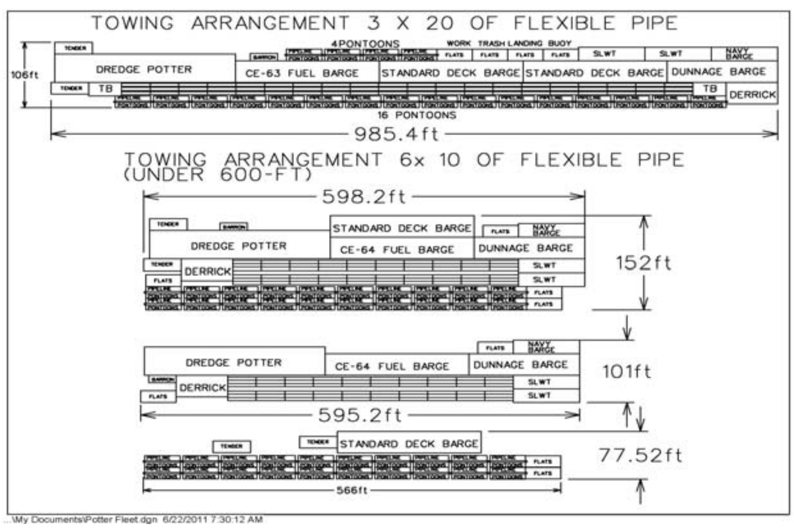


**Figure 14:** Towing Configuration Drawing

The floating hose was more easily connected on a slightly sloped area. The flexible pipe is mostly designed for use on beaches where sloped areas are common. However, sloped areas are not readily available on the Mississippi River. The crew experimented with connecting the sections of pipe on a work barge and then dragging the assembled parts into the water (Figure 15). After connecting a few sections in this manner, the crew designed and fabricated a framework and barge system to improve the overall efficiency of assembly. Figure 16 is a conceptual drawing of the framework connected to the barges. To assemble the pipe into large sections, the hose is slid in between the barges and connected while floating in the water (Figure 16). When not in use, the flexible floating pipe will be broken down, covered, and stored on a barge.

**Figure 15:** Initial Assembly Method

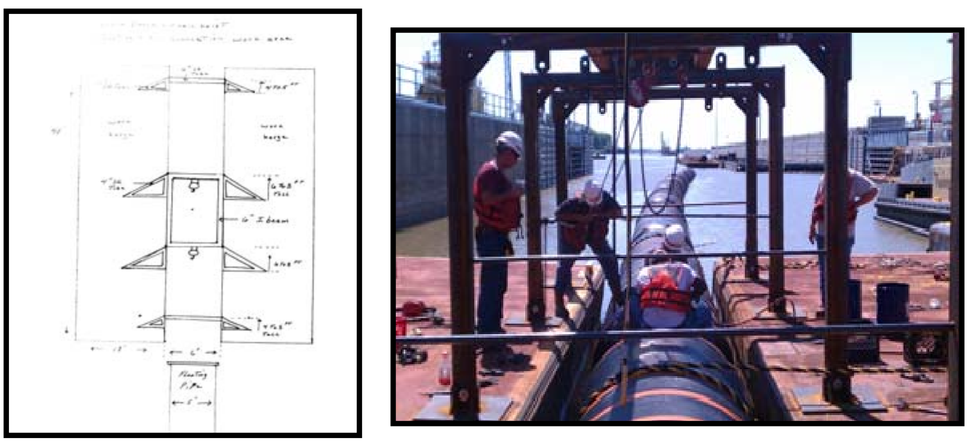

**Figure 16:** Conceptual Drawing of Framework (left) and Crew Assembling Flexible Pipe (right)

A spill barge for the islands creation has still not been designed or purchased. It is possible that a similar concept of the spill barge designed by Luhr Brothers Dredging Company will be used (Figure 17).

**Figure 17:** Luhr Brothers Dredging Company Spill Barge

## 4. Types of Depositional Areas

On the Middle Mississippi River there are three main types of depositional areas: sandbars, non-vegetated islands, and vegetated islands.

Sandbar is a general term that could refer to side bars, submerged sand bars, and point bars of low elevation. These features are ephemeral because the bars are of low elevation with respect to normal river stages and are frequently flooded. The bars often times disappear as a result of flows transporting the bar material and depositing it in a location farther downstream. Bars are typically very dynamic features, classified as wetted edge habitats. Wetted edge habitats are an area of a stream or river near the edge of flows where the exposed and submerged ecological areas meet. Because these areas are frequently overtopped, minimal or no vegetation can take root.

Stable non-vegetated islands have slightly higher elevations than ephemeral sandbar features and thus require higher river stages to be submerged. These bars remain in the same general location because they consist of substantial material such as clay or gravel and/or there was once heavy vegetation that has been cut down and the root wads remain. These islands are isolated, have minimal or no vegetation, and their heights may vary year to year. This is the ideal habitat for the federally endangered least tern[1], which prefer to nest on barren to sparsely vegetated sand or gravel bars un-inhabited by predators.

Vegetated islands are considered relatively permanent features because of the higher elevations and resistance to erosion is provided by the vegetation. Vegetation found on the Middle Mississippi River islands commonly consists of scrub brush, willows, and/or cottonwood trees. Typically, islands are more resistant to erosion than bars. However, despite being less susceptible to erosion, some islands are protected by a hydraulic structure. These rock structures are typically placed on the upstream end of the island, but revetment can be placed anywhere along the perimeter of the island if needed.

## 5. Formation of Depositional Areas

The initial formation of depositional areas is a result of the interaction of hydraulic processes with the planform and geometry of the river. Where the river is narrow, sediment is suspended and transported more efficiently as a result of increased velocities. When the river widens, velocities decrease. Consequently, sediment deposits in the channel. Additionally, large amounts of sediment can fall out of suspension when the water level falls at a rapid rate. Gradual degradation of banks can increase deposition downstream. A flood can suddenly cut off a section of land as well.

Island shape and size can be affected by a number of things, such as the channel geometry, slope, hydrograph, sediment characteristics, vegetation, and hydraulic structures. As seen in Figure 17, the existing islands have unique shapes as a direct result of the previously mentioned factors specific to that

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[1] "Least Tern (Interior Population)." *U.S. Fish and Wildlife Service*, 9 Mar. 2011. http://www.fws.gov/midwest/endangered/birds/tern.html. 12 Aug. 2011.

reach of river. Because of the combination of several factors influencing the size and shape of existing islands, it would be unrealistic to design an island or bar and expect the flexible dredge pipe to create a permanent feature exactly as it's drawn in the plans and specifications. Even if the dredge was capable of creating the bar or island shape as designed, the river would ultimately alter its shape and size.

## 6. Size and Shape of Existing Islands

In order to provide a physical, biological, and economical reference for the creation of sandbars and islands using dredge disposal, an analysis was done to establish the relative sizes and shapes of islands that exist in the Middle Mississippi River (Table 1 and Figure 17). The geometry of the existing islands and locations of least tern and pallid sturgeon sightings on the Mississippi River (miles 200 to 0) were obtained using aerial photographs, bathymetric surveys, and input from the US Fish and Wildlife Service (USFWS), Missouri Department of Conservation (MDC), Illinois Department of Natural Resources (IDNR), and MVS Environmental Branch personnel.

The area, width, and length of each existing island were measured to determine their size and material volume depending upon their top elevation. There is no detailed topography of the existing islands, but there are bathymetric surveys at high water levels. Based on these surveys and the fact that the top of islands are never higher than the top of bank, vegetated islands were assumed to have an elevation of +25 to +30 Low Water Reference Plane (LWRP*), non-vegetated islands were assumed to have an elevation of +20 to +25 LWRP, and ephemeral bars were assumed to have an elevation below +20 LWRP. The assumptions are based upon the ability to support long-term vegetation at or near top of bank elevation, which is typically +25 to +30 ft LWRP. These elevations and measurements were used to calculate the material volume for each island. Additionally, the width-length ratio was calculated and an average width-length ratio was determined.

**Table 1:** Existing Island Characteristics

| Island Name | River Mile | Reach Type | Vegetation | Providing Habitat | | Area (ft^2) | Area (Acres) | Area (yd²) | Material Volume: Vegetated (yd³) | Material Volume: Non-Vegetated (yd³) | Geometry | Length (ft) | Width (ft) | W/L Ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Palid Sturgeon | Least Tern | | | | | | | | | |
| Angelo Towhead 1 | 3 | Curve | High | | | 25,339,147 | 582 | 2815461 | 28,154,608 | 337,855 | Teardrop | 10,714 | 3220 | 0.30 |
| Angelo Towhead 2 | 3.5 | Curve | High | | | 711,368 | 16 | 79041 | 790,409 | 9,485 | Football | 2,612 | 441 | 0.17 |
| Boston Bar | 9 | Straight | High | | | 26,196,150 | 601 | 2910683 | 29,106,833 | 349,282 | Teardrop | 12,249 | 2940 | 0.24 |
| Island No. 29 | 13 | Curve | High | | | 4,175,262 | 96 | 463,918 | 4,639,180 | 55,670 | Teardrop | 6,790 | 674 | 0.10 |
| Island No. 28 | 14 | Curve | High | YES (MC) | | 3,633,383 | 83 | 403,709 | 4,037,092 | 48,445 | Oval | 2,820 | 1,232 | 0.44 |
| Browns Bar 1 | 23 | Curve | Moderate | | YES | 15,041,028 | 345 | 1,671,225 | 16,712,253 | 200,547 | Football | 7,902 | 2,817 | 0.36 |
| Browns Bar 2 | 24.2 | Curve | Moderate | | YES | 1,225,271 | 28 | 136,141 | 1,361,412 | 16,337 | Football | 2,168 | 830 | 0.38 |
| Buffalo | 25.5 | Straight | High | | | 5,422,675 | 124 | 602,519 | 6,025,194 | 72,302 | Teardrop | 6,815 | 1,349 | 0.20 |
| Bumgard | 30 | Smooth Curve | Low | YES (US) | YES | 10,341,205 | 237 | 1,149,023 | 11,490,228 | 137,883 | Football | 6,873 | 2,336 | 0.34 |
| Burnham | 38 | Straight | High | | | 56,782,544 | 1304 | 6,309,172 | 63,091,716 | 757,101 | Teardrop | 19,516 | 3,515 | 0.18 |
| RM 40-41 Island 1 | 40 | Straight | High | | | 4,580,189 | 105 | 508,910 | 5,089,099 | 61,069 | Teardrop | 5,270 | 1,177 | 0.22 |
| RM 40-41 Island 2 | 40.5 | Straight | High | | | 348,675 | 8 | 38,742 | 387,417 | 4,649 | Teardrop | 1,525 | 337 | 0.22 |
| RM 40-41 Island 3 | 41 | Straight | High | | | 2,184,888 | 50 | 242,765 | 2,427,653 | 29,132 | Teardrop | 4,143 | 609 | 0.15 |
| Marquette | 49 | Curve | Moderate | | YES | 30,664,914 | 704 | 3,407,213 | 34,072,127 | 408,866 | Teardrop | 11,554 | 3,876 | 0.34 |
| Devils | 57 | Curve | High | | | 92,695,123 | 2128 | 10,299,458 | 102,994,581 | 1,235,935 | Other | 30,632 | 4,713 | 0.15 |
| Schenimann Chute 1 | 58 | Smooth Curve | High | | | 13,545,871 | 311 | 1,505,097 | 15,050,968 | 180,612 | Teardrop | 8,356 | 2,079 | 0.25 |
| Schenimann Chute 2 | 58.5 | Smooth Curve | High | | | 722,066 | 17 | 80,230 | 802,296 | 9,628 | Oval | 1,576 | 574 | 0.36 |
| Schenimann Chute 3 | 60.5 | Smooth Curve | High | | | 19,605,685 | 450 | 2,178,409 | 21,784,094 | 261,409 | Oval | 12,976 | 2,248 | 0.17 |
| Schenimann Chute 4 | 62.2 | Smooth Curve | High | | | 524,513 | 12 | 58,279 | 582,792 | 6,994 | Oval | 1,163 | 454 | 0.39 |
| Crawford | 73 | Straight | High | YES (DS) | | 19,372,370 | 445 | 2,152,486 | 21,524,856 | 258,298 | Teardrop | 11,640 | 2,871 | 0.25 |
| Next Grand Tower | 78 | Straight | High | YES (US +DS) | | 2,234,195 | 51 | 248,244 | 2,482,439 | 29,789 | Football | 3,250 | 100 | 0.03 |
| Jones Towhead | 96 | Smooth Curve | High | | | 18,086,459 | 415 | 2,009,607 | 20,096,066 | 241,153 | Teardrop | 9,059 | 3,140 | 0.35 |
| Liberty Bar 1 | 97 | Smooth Curve | High | | | 361,383 | 8 | 40,154 | 401,537 | 4,818 | Other | 850 | 532 | 0.63 |
| Liberty Bar 2 | 97.5 | Smooth Curve | High | | | 3,974,713 | 91 | 441,635 | 4,416,348 | 52,996 | Teardrop | 3,985 | 1,318 | 0.33 |
| RM 98-100 Island 1 | 98.4 | Straight | High | | | 104,079 | 2 | 11,564 | 115,643 | 1,388 | Teardrop | 618 | 222 | 0.36 |
| RM 98-100 Island 2 | 98.6 | Straight | High | | | 503,480 | 12 | 55,942 | 559,422 | 6,713 | Oval | 1,187 | 501 | 0.42 |
| RM 98-100 Island 3 | 99.2 | Straight | High | | | 371,470 | 9 | 41,274 | 412,744 | 4,953 | Oval | 1,244 | 363 | 0.29 |
| RM 98-100 Island 4 | 99.5 | Straight | High | | | 139,435 | 3 | 15,493 | 154,928 | 1,859 | Oval | 685 | 268 | 0.39 |
| RM 98-100 Island 5 | 99.6 | Straight | High | | | 44,847 | 1 | 4,983 | 49,830 | 598 | Oval | 368 | 148 | 0.40 |
| RM 98-100 Island 6 | 99.8 | Straight | High | | | 79,120 | 2 | 8,791 | 87,911 | 1,055 | Oval | 546 | 217 | 0.40 |
| Liberty | 100.5 | Straight | High | | | 2,326,199 | 53 | 258,467 | 2,584,666 | 31,016 | Teardrop | 4,485 | 656 | 0.15 |
| Rockwood | 102 | Straight | High | | | 14,398,235 | 331 | 1,599,804 | 15,998,039 | 191,976 | Football | 7,242 | 2,648 | 0.37 |
| Crains 1 | 104 | Straight | High | YES (MC) | | 548,069 | 13 | 60,897 | 608,966 | 7,308 | Football | 1,370 | 592 | 0.43 |
| Crains 2 | 104.5 | Straight | High | YES (MC) | | 2,947,951 | 68 | 327,550 | 3,275,501 | 39,306 | Football | 4,042 | 1,033 | 0.26 |
| Crains 3 | 105 | Straight | High | YES (MC) | | 2,906,752 | 67 | 322,972 | 3,229,724 | 38,757 | Football | 4,410 | 918 | 0.21 |
| Beaver 1 | 116 | Curve | Moderate | YES (DS) | | 518,962 | 12 | 57,662 | 576,624 | 6,919 | Teardrop | 1,641 | 499 | 0.30 |
| Beaver 2 | 116.5 | Curve | Moderate | YES (MC) | | 551,419 | 13 | 61,269 | 612,688 | 7,352 | Teardrop | 1,881 | 395 | 0.21 |
| Beaver 3 | 116.6 | Curve | High | YES (US) | | 13,253,100 | 304 | 1,472,567 | 14,725,667 | 176,708 | Other | 6,701 | 3,794 | 0.57 |
| Beaver 4 | 117 | Curve | Moderate | YES (MC) | | 1,128,683 | 26 | 125,409 | 1,254,092 | 15,049 | Oval | 2,467 | 459 | 0.19 |
| Moro 1 | 121 | Curve | Moderate | YES (DS) | | 27,098,481 | 622 | 3,010,942 | 30,109,423 | 361,313 | Football | 9,802 | 4,142 | 0.42 |
| Moro 2 | 122.5 | Curve | High | YES (MC) | | 2,306,365 | 53 | 256,263 | 2,562,628 | 30,752 | Teardrop | 3,182 | 1,003 | 0.32 |
| Establishment 1 | 130.5 | Curve | High | YES (MC) | | 562,617 | 13 | 62,513 | 625,130 | 7,502 | Oval | 2,275 | 276 | 0.12 |
| Establishment 2 | 131.5 | Curve | High | YES (MC) | | 6,115,663 | 140 | 679,518 | 6,795,181 | 81,542 | Football | 5,931 | 1,598 | 0.27 |
| Fort Chartres | 133 | Smooth Curve | High | YES (DS+MC) | | 15,256,421 | 350 | 1,695,158 | 16,951,579 | 203,419 | Teardrop | 9,366 | 2,053 | 0.22 |
| Salt Lake Chute | 138 | Straight | Moderate | YES (MC) | | 15,293,585 | 351 | 1,699,287 | 16,992,872 | 203,914 | Oval | 12,716 | 1,774 | 0.14 |
| Osbourne Chute | 146 | Smooth Curve | High | | | 11,416,361 | 262 | 1,268,485 | 12,684,846 | 152,218 | Teardrop | 8,413 | 1,913 | 0.23 |
| Calico | 148 | Straight | High | | | 2,936,322 | 67 | 326,258 | 3,262,580 | 39,151 | Football | 4,161 | 1,262 | 0.30 |
| Fines Bluff 1 | 160.6 | Smooth Curve | Moderate | | | 125,673 | 3 | 13,964 | 139,637 | 1,676 | Teardrop | 804 | 217 | 0.27 |
| Fines Bluff 2 | 161 | Smooth Curve | Moderate | | | 1,531,360 | 35 | 170,151 | 1,701,511 | 20,418 | Football | 2,667 | 756 | 0.28 |
| Carrol | 168 | Straight | Moderate | | | 2,815,889 | 65 | 312,877 | 3,128,766 | 37,545 | Football | 5,058 | 891 | 0.18 |

Notes:
*LWRP is the hydraulic reference plane established from long term observations of the river's stage, discharge rates, and flow duration periods. The low water profile was developed about the 97% flow duration line – approximately 54,000 cubic feet per second (cfs).[2] LWRP equals 0 ft at 379.4 ft elevation at RM 180.0, St. Louis, Mo
*Material volume was calculated using an elevation of 30 ft for vegetated island and 25 ft for non-vegetated island (assuming that the initial elevation is 0 referenced to Low Water Reference Plane - LWRP). These calculations are only estimates, actual island elevation may vary.
*MC = Main Channel, US = Upstream, and DS = Downstream

[2] Gordon P.E., David. "Re: LWRP Data." Message to Ashley Cox. 8 Aug. 2011. Email.

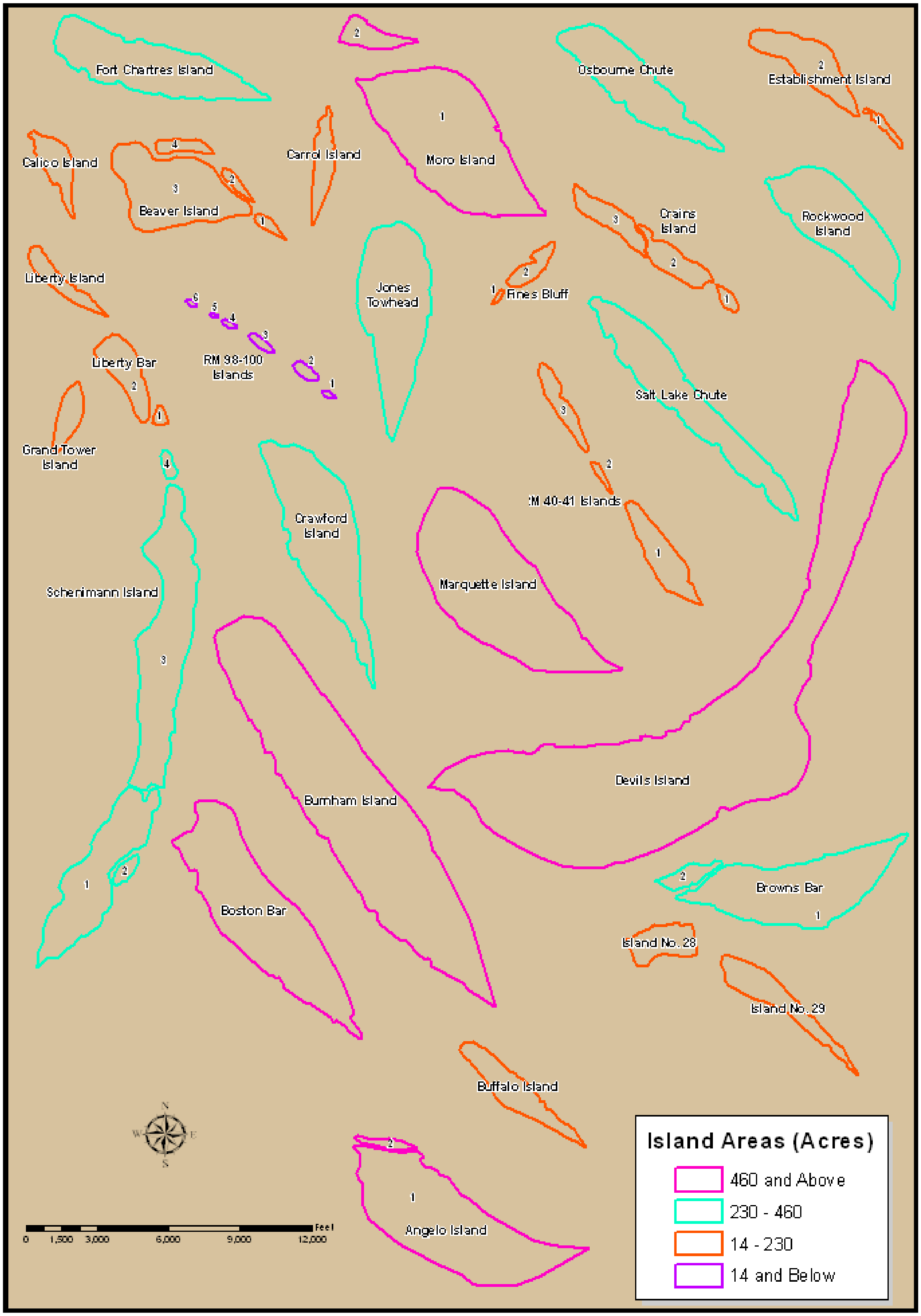


**Figure 17:** Existing Islands in Upper Mississippi River

## 7. Dredge Disposal Opportunities in the Middle Mississippi River

Based on historic dredging records within the St. Louis District between the years of 1990 – 2010, eight repetitive dredging locations were selected as potential locations for sandbar or island creation. These dredging locations give a wide sample range of dredging amounts. The average amount of dredging material ($ft^3$) removed per dredging event was calculated for each location (Table 2). This average is the amount of material that would be available in that specific location to create a depositional feature.

**Table 2:** Dredge Material Calculations at +25 LWRP for Proposed Islands

| RM 0 - 1.5 | | RM 1.5 - 3.0 | | RM 4.0 - 5.0 | | RM 8.0 - 10.0 | | RM 24.0 - 25.0 | | RM 38.0 - 40.0 | | RM 80.0 - 82.5 | | RM 172.8-173.5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YEAR | DREDGE MATERIAL | YEAR | DREDGE MATERIAL | YEAR | DREDGE MATERIAL | YEAR | DREDGE MATERIAL | YEAR | DREDGE MATERIAL | YEAR | DREDGE MATERIAL | YEAR | DREDGE MATERIAL | YEAR | DREDGE MATERIAL |
| 1990 | | 1990 | | 1990 | 915,118 | 1990 | | 1990 | | 1990 | | 1990 | | 1990 | |
| 1991 | | 1991 | | 1991 | 417,466 | 1991 | | 1991 | | 1991 | | 1991 | | 1991 | |
| 1992 | 29,417 | 1992 | | 1992 | | 1992 | | 1992 | | 1992 | | 1992 | 81,215 | 1992 | |
| 1993 | | 1993 | | 1993 | | 1993 | | 1993 | | 1993 | | 1993 | | 1993 | |
| 1994 | | 1994 | | 1994 | | 1994 | | 1994 | | 1994 | | 1994 | 63,533 | 1994 | 175,177 |
| 1995 | | 1995 | | 1995 | 404,488 | 1995 | | 1995 | 208,809 | 1995 | 233,988 | 1995 | | 1995 | 240,784 |
| 1996 | | 1996 | | 1996 | | 1996 | | 1996 | | 1996 | | 1996 | 29,251 | 1996 | |
| 1997 | 309,614 | 1997 | 299,028 | 1997 | 367,914 | 1997 | 215,544 | 1997 | | 1997 | 309,549 | 1997 | | 1997 | |
| 1998 | | 1998 | | 1998 | 76,324 | 1998 | | 1998 | 134,401 | 1998 | 247,665 | 1998 | 127,721 | 1998 | |
| 1999 | 344,745 | 1999 | 77,190 | 1999 | 372,902 | 1999 | 269,885 | 1999 | 65,996 | 1999 | | 1999 | 255,646 | 1999 | 37,817 |
| 2000 | 616,610 | 2000 | 187,522 | 2000 | 425,620 | 2000 | 388,948 | 2000 | | 2000 | 649,651 | 2000 | 201,301 | 2000 | 127,239 |
| 2001 | | 2001 | | 2001 | 412,401 | 2001 | 80,049 | 2001 | | 2001 | | 2001 | 146,532 | 2001 | |
| 2002 | | 2002 | 87,089 | 2002 | 137,902 | 2002 | | 2002 | | 2002 | 295,021 | 2002 | 192,656 | 2002 | 302,900 |
| 2003 | | 2003 | | 2003 | | 2003 | | 2003 | | 2003 | 285,854 | 2003 | 160,455 | 2003 | 55,162 |
| 2004 | | 2004 | | 2004 | | 2004 | | 2004 | | 2004 | | 2004 | 210,475 | 2004 | 95,600 |
| 2005 | 297,563 | 2005 | | 2005 | | 2005 | 161,983 | 2005 | | 2005 | | 2005 | 80,155 | 2005 | 93,819 |
| 2006 | 67,716 | 2006 | 99,359 | 2006 | | 2006 | 162,283 | 2006 | 109,807 | 2006 | 179,699 | 2006 | 107,438 | 2006 | 55,842 |
| 2007 | 88,778 | 2007 | 96,669 | 2007 | | 2007 | 140,997 | 2007 | 69,472 | 2007 | 156,117 | 2007 | 64,683 | 2007 | 88,745 |
| 2008 | 156,566 | 2008 | 129,809 | 2008 | | 2008 | | 2008 | 139,811 | 2008 | 75,542 | 2008 | 33,346 | 2008 | 147,234 |
| 2009 | | 2009 | | 2009 | | 2009 | | 2009 | 166,284 | 2009 | 157,800 | 2009 | 130,254 | 2009 | 293,702 |
| 2010 | | 2010 | | 2010 | | 2010 | | 2010 | 84,292 | 2010 | 265,991 | 2010 | 104,543 | 2010 | 118,647 |
| **AVG ($YD^3$)** | 238,876 | **AVG ($YD^3$)** | 139,524 | **AVG ($YD^3$)** | 392,237 | **AVG ($YD^3$)** | 202,813 | **AVG ($YD^3$)** | 122,359 | **AVG ($YD^3$)** | 259,716 | **AVG ($YD^3$)** | 124,325 | **AVG ($YD^3$)** | 132,657 |
| **AVG ($FT^3$)** | 6,449,655 | **AVG ($FT^3$)** | 3,767,140 | **AVG ($FT^3$)** | 10,590,405 | **AVG ($FT^3$)** | 5,475,943 | **AVG ($FT^3$)** | 3,303,693 | **AVG ($FT^3$)** | 7,012,334 | **AVG ($FT^3$)** | 3,356,782 | **AVG ($FT^3$)** | 3,581,739 |
| If placing 15' of material onto existing bathymetry (to yield an island elevation of +25 LWRP), the island can have an area of: | | If placing 15' of material onto existing bathymetry (to yield an island elevation of +25 LWRP), the island can have an area of: | | If placing 15' of material onto existing bathymetry (to yield an island elevation of +25 LWRP), the island can have an area of: | | If placing 15' of material onto existing bathymetry (to yield an island elevation of +25 LWRP), the island can have an area of: | | If placing 15' of material onto existing bathymetry (to yield an island elevation of +25 LWRP), the island can have an area of: | | If placing 15' of material onto existing bathymetry (to yield an island elevation of +25 LWRP), the island can have an area of: | | If placing 15' of material onto existing bathymetry (to yield an island elevation of +25 LWRP), the island can have an area of: | | If placing 15' of material onto existing bathymetry (to yield an island elevation of +25 LWRP), the island can have an area of: | |
| 429,977 | $FT^2$ | 251,143 | $FT^2$ | 706,027 | $FT^2$ | 365,063 | $FT^2$ | 220,246 | $FT^2$ | 467,489 | $FT^2$ | 223,785 | $FT^2$ | 238,783 | $FT^2$ |

In order to determine the size of a generic island created by dredge material, it was assumed that the dredge material would be placed on existing bathymetry that had elevations of +10 ft LWRP or above (vegetated islands with heights of >+25 LWRP are targeted in this example). Placing dredge material at or above this elevation would allow for a larger footprint or area visible above normal water levels. Using a starting elevation less than +10 ft LWRP would result in the need for large quantities of material to bring the elevation of the feature to the assumed +25 LWRP height, thus drastically reducing the overall area of the island. Once this assumption was established, the size of the proposed islands could be calculated.

To comprehend the size of a proposed +25 LWRP island using dredge material, the island size was calculated for each location based upon the assumptions and Table 2 data. To do this, the average amount of dredge material removed ($ft^3$) per dredging event was divided by the vertical height of dredge material (ft) to be placed on top of the existing bathymetry, which yielded the area/footprint ($ft^2$). Once the island size calculation was completed (Table 2), the average size of the proposed islands was roughly drawn next to the average size of the existing islands in Arc Map and can be seen in Figure 18.

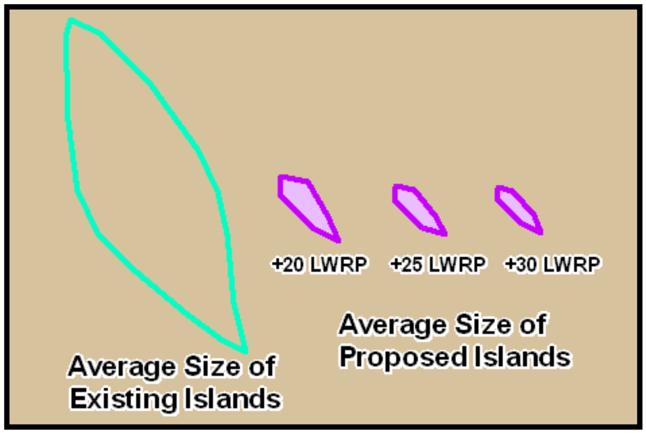


**Figure 18:** Comparison of Existing Islands and Proposed Islands' Average Size (1:45,000)

## 8. Methods to Stabilize Features

Once elevation, location, and starting geometry are determined, the required protection structures must be considered. Essentially there are four main alternatives to protect a depositional feature built completely out of dredge material: no hydraulic structures, hydraulic structures, plantings, or a combination of structures and plantings.

### A. No Hydraulic Structure

Any kind of depositional feature constructed from dredge disposal alone will be prone to erosion. Without the protection of an existing or newly constructed hydraulic structure, the island or bar will degrade over time. This method would only be recommended for the creation of an ephemeral bar discussed on page 9 of this report.

### B. Hydraulic Structure

Hydraulic structures would stabilize any feature created from dredge disposal. Structure options include existing rock structures that currently protect islands and innovative structures which are not yet out in the river. These hydraulic structures would be recommended for permanent depositional features.

#### i. Commonly Used Structures

A commonly used structure to protect existing islands is the bull nosed dike. A bull nose dike is a structure offset immediately upstream of the island (Figure 19). In addition, on a much larger scale the dike acts as a blunt nosed chevron (Figure 20), which has the ability to split flows in a manner that contributes to slightly deepening a side channel while maintaining channel navigation[3]. Besides protection, these structures promote deposition downstream of the scour hole mentioned above (Figure 20, right side).

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[3] Davinroy, Robert D. et al. "Design of Blunt Nose Chevrons." *USACE Applied River Engineering Center*. 30 June 2011. http://www.mvs.usace.army.mil/arec/reports_chevron.html.

**Figure 19:** Bullnose Dikes at Blackbird Island, RM 292.1R (left) and Pharrs Island, RM 277.5L (right)

**Figure 20:** Blunt Nosed Chevrons at RM 130.0R (left) and RM 183.0-182.0R (right)

Another type of structure that has been used to protect depositional features is dikes. Usually dike fields, a set of two or more dikes working together, are utilized because they provide shelter from high velocities. The downstream dikes are usually notched to allow additional flow around the island (Figure 21).

**Figure 21:** Looking Downstream at Mile 100 Islands

Additionally, once the island is well established and the shape of the island is satisfactory, then revetment can be used to further stabilize the island's banks (Figure 22).

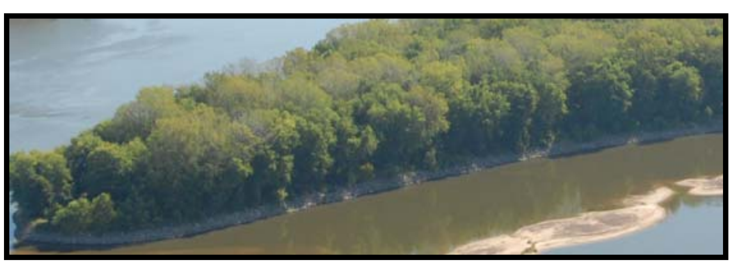

**Figure 22:** Revetment on Carroll Island (RM 270.0L)

### ii. Innovative Structures

Although the existing hydraulic structures have protected islands for years, they are not the only option. New creative structures could be designed based upon current river engineering knowledge and even tested in Hydraulic Sediment Response (HSR) models. When developing a new structure for sustaining a created island, the shape, placement by the created depositional feature, and the location of the depositional feature itself near existing hydraulic structures must be taken into account.

#### 1. Design Parameters for Hydraulic Structures

***a. Shape***

The shape of the structure will greatly influence the size and shape of the scour pattern and ultimately the created depositional feature. Figure 23 is a generalized schematic of typical bed formations near three different structures. If the structure is curved, like a chevron, scour will develop at the head of the structure and off the outside of the two legs (Figure 23a). When a chevron is overtopped, a large scour hole will develop in between the two legs of the chevron. If the structure is angled in a "V" formation, scour will develop off the "outside" of the two legs (Figure 23b). When the "V" structure is overtopped, a scour hole will also develop in between the two legs. If the structure is a longitudinal dike, the scour pattern will be wider than and not as long as the others previously mentioned (Figure 23c). The scour pattern by a longitudinal dike will be the same whether the structure is overtopped or not. Another consideration is the angle of the structure to predominant flows. At normal flow, structures with extended legs, like in Figure 23a and 23b, provide shelter for the depositional feature. The more protection the structure provides, the larger the footprint the created depositional feature will sustain. The deposition will occur downstream of the scour hole, as described in the following sections.

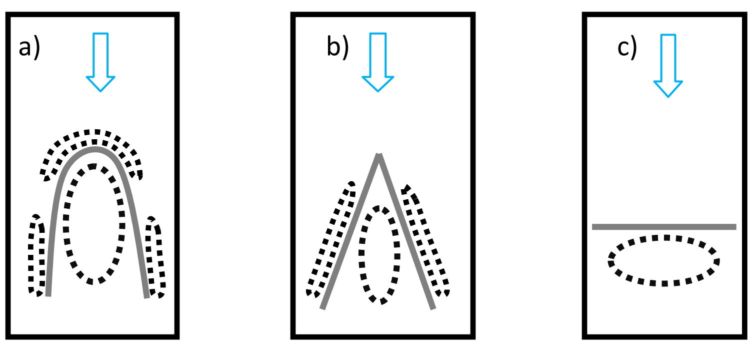


**Figure 23:** General Scour Patterns near Structures
a) Curved Structure b) V Structure c) Longitudinal Structure

***b. Location of Structure***

The most important parameter for location of the structure, and ultimately the created depositional feature, is it cannot have any negative impacts to the navigation channel. Therefore the structure and island must be located outside of the navigation channel. Typically, any structure in the river is prone to scour immediately downstream. After evaluating the bathymetry downstream of existing structures on the Middle Mississippi River, the scour generally extended approximately 250 ft downstream of the structure. As a result, the structure should be placed approximately 250 ft upstream of where the created depositional feature's location is desired. This allows the energy at high flows to overtop the structure, expend the higher energy downstream of the structure as scour, and then drop the sediment out in the slower moving water just downstream of the scour. The created depositional feature will benefit in two ways. First, the feature is in slower moving water, which means the feature will be less prone to erosion. Second, the depleted energy in the water will allow the suspended sediment to fall out in this general vicinity, adding to the depositional feature's size and/or height.

### *c. Location of Depositional Feature*

Another viable alternative is to design the location of the created depositional feature behind an existing hydraulic structure. It would require less construction time and be economically beneficial to utilize existing structures. Favorable structures that lend themselves to the protection of depositional features are chevrons and typically any dike (i.e. longitudinal, L shaped, W shaped, etc). However, the velocities and bathymetry near those structures need to be analyzed to determine if they will adequately stabilize and protect a created depositional feature. If there are high velocities directly downstream of a structure, most likely because of a notch, the depositional feature will erode. The location of a notch in a structure is an important factor when determining the location of a depositional feature. The feature should not be directly downstream and in line with a notch. A feature should be offset from the notch (Figure 24a and b). An ideal situation would be to locate an area downstream of an existing structure that has minor deposition and low energy. Conversely, if there is not enough energy behind the structure, over time the depositional feature could become part of the existing bank. Looking back at Table 2, some of the proposed depositional features could utilize existing structures (i.e. Figure 25: c, e, and part of f).

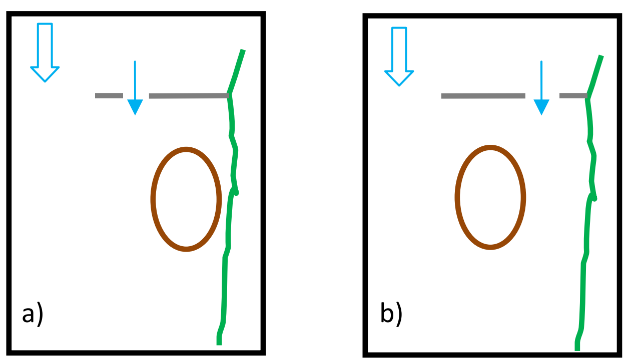


**Figure 24:** Depositional Feature Location Downstream of Notched Dikes
a) Feature Offset to Right of Notch b) Feature Offset to Left of Notch

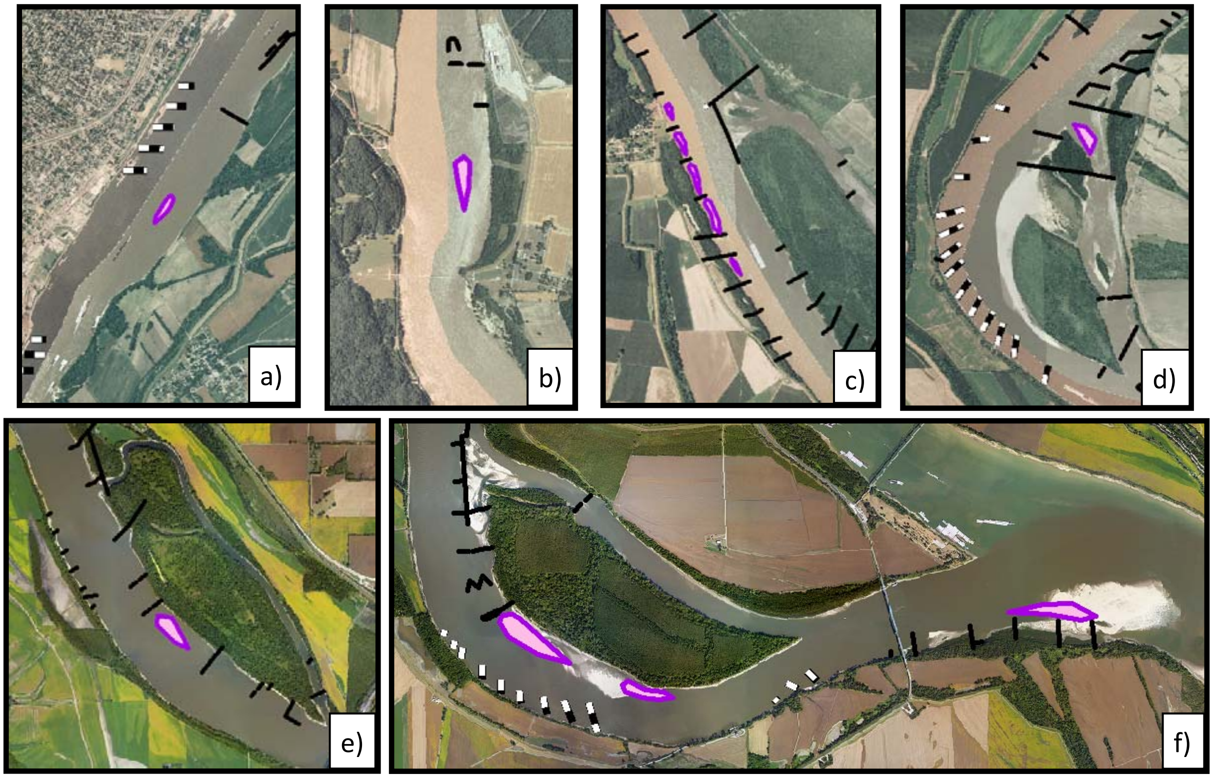


**Figure 25:** Proposed Islands (1:20,000)
(Starting from top left and clockwise: a) RM 173.5-172.8, b) RM 82.5-80.0, c) RM 40.0-38.0, d) RM 25.0-24.0, e) RM 10.0-8.0, f) RM 5.0-0.0)

### *d. Height of Structure*

The height of the hydraulic structure depends upon the desired depositional feature, its purpose, and the probability of being overtopped. In general, the higher the structure, the higher the island, which increases the island's stability. If the goal is to create a vegetated island, the structure should be no lower than +25 LWRP. However, if funding is insufficient for such a significant structure, then the structure height could be lowered to +18 LWRP and when possible, additional dredged material could be placed on top of the depositional feature. If the goal is to create an island suitable for least terns, then the structure height should depend upon the probability of the island being overtopped. The island should be constructed to a height that will inhibit the growth of vegetation, but still allow for a minimum of 50 consecutive days of exposure during the May 15 to August 31 breeding season. This is based upon the federally endangered species, the least tern[4], which requires at least 50 consecutive days of exposed habitat to complete courtship, lay eggs, incubate a clutch (21 days), and raise young to fledging (approximately 21 days). However, least terns are more likely to use sites that are continuously exposed for at least 100 days during the period May 15 to August 31[5]. With the use of historical river stage data

4 "Listings and Occurrences for Missouri". *U.S. Fish and Wildlife Service*, 30 June 2011. http://ecos.fws.gov/tess_public/pub/stateListingAndOccurenceIndividual.jsp?state=MO&s8fid=112761032792&s8fid. 30 June 2011.

5 Allen, Teresa C. *Middle Mississippi River Islands: Historical Distribution, Restoration Planning, and Biological Importance*. Diss. University of Missouri, 2010. St. Louis: Unpublished.

for specific river miles and UNET[6], a one-dimensional unsteady flow hydrologic modeling tool, an approximate elevation that is required for probable flooding during the selected range of days for those specific river miles can be determined. That is, any structure or feature of that particular elevation will have a given probability of staying exposed for the duration of 'n' number of days. Table 3 is an example of the information obtained from UNET for RM 175.0 for 50, 75, and 100 days of exposure.

For instance, consider the proposed depositional feature near RM 173.0 (from Table 2). The LWRP elevation at this location is 374.5 ft. Following the previously mentioned assumption that existing vegetated islands have an average elevation of +25 ft LWRP, the structure would be 399.5 ft elevation. Referencing Table 3, it shows that there is approximately 40% cumulative probability of the proposed depositional feature being exposed (or un-flooded) for 100 consecutive days during flooding season. The proposed island would theoretically be overtopped frequently enough that heavy vegetation would not take root, while maintaining an adequate elevation for least tern breeding. If the island were to have an average elevation of +30 ft LWRP, the structure would be 404.5 ft and have approximately 63% cumulative probability that the proposed feature would be exposed for 100 consecutive days. A five foot increase in the structure's height would significantly reduce the size of the island's footprint (assuming a fixed quantity of dredge material) and significantly increase the opportunity for heavy vegetation to take root on the island, thus reducing the overall appeal of the island to the least tern.

**Table 3:** Probability Output from UNET

| RM 175 Cumulative Probability | Minimum Elevation | | |
|---|---|---|---|
| | 50 Days | 75 Days | 100 Days |
| 0.95 | 382.4 | 384.8 | 389.8 |
| 0.90 | 385.3 | 390.4 | 391.4 |
| 0.85 | 387.0 | 391.1 | 394.1 |
| 0.80 | 388.7 | 393.1 | 394.9 |
| 0.75 | 389.7 | 394.2 | 396.5 |
| 0.70 | 390.7 | 394.9 | 397.2 |
| 0.65 | 391.6 | 395.7 | 398.8 |
| 0.60 | 391.8 | 397.0 | 399.1 |
| 0.55 | 392.3 | 397.9 | 400.2 |
| 0.50 | 393.1 | 398.9 | 401.1 |
| 0.45 | 393.6 | 399.6 | 401.6 |
| 0.40 | 394.4 | 400.4 | 403.6 |
| 0.35 | 395.6 | 402.6 | 405.5 |
| 0.30 | 396.2 | 403.6 | 406.5 |
| 0.25 | 396.6 | 405.5 | 407.3 |
| 0.20 | 398.7 | 406.4 | 408.2 |
| 0.15 | 401.4 | 406.9 | 411.3 |
| 0.10 | 403.4 | 407.6 | 412.2 |
| 0.05 | 405.1 | 410.6 | 415.2 |

Note: Cumulative probability is the probability of being flooded.

[6] Barkau, R.L. 1995. UNET: One-dimensional Unsteady Flow through a Full Network of Open channels. Version 3.0 U.S. Army Corps of Engineers, Hydraulic Engineering Center. Davis, CA.

### C. Plantings

Another island stabilization alternative is plantings. This method would involve planting trees, most commonly willows (Figure 22), after the spring high water period has passed and the island is exposed. The willows are used for bank and island stabilization and would enhance riparian habitat. This alternative would most likely require some type of maintenance to ensure the willows take root and successfully stabilize the island. This method could be used for both vegetated and non-vegetated islands. To achieve a stable non-vegetated island, after the willows have matured and their roots are sufficiently stabilizing the island, the willows could be cut down. Annual maintenance may be required to ensure substantial vegetation does not grow back. To maintain a stable vegetated island, the willows would remain.

**Figure 22:** Willow Cuttings Planted (left) and Mature Willows (right)

### D. Combinations

The last stabilization alternative would be to use a hydraulic structure and plantings in some kind of combination depending on the purpose of the depositional feature. The previous sections can be used for design guidance.

## 9. Conclusions

Use of flexible dredge pipe has great potential to create islands from dredge material in the Mississippi River. Based on available data, work by others, hydraulic considerations, and past experiences, a number of conclusions can be drawn and used in planning and designing island locations. Those include:

- Islands created will be substantially smaller than the majority of existing vegetated and non-vegetated permanent islands on the Middle Mississippi River.
- Island footprints are going to be highly variable, and highly dependent on available material and the LWRP of the placement site. Site specific determination of the best island types to create will be required.

- Based on existing island morphology, generally speaking, vegetated islands are going to require a top elevation above +25 LWRP; non-vegetated permanent islands would require an elevation between +20 and +25 LWRP; and elevations below +20 LWRP are likely to result in ephemeral islands.

- Maintaining a permanent island is likely going to require protecting the island. Prior to the establishment of permanent vegetation, the height of the island is likely to be constrained by the height of the protective structure.

- Based on existing data, protective structures should be 250 ft upstream of the proposed island site.

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