The Project

Engineers and biologists are typically thought to be at odds when addressing environmental issues. Each is often faced with agendas that appear to be in direct opposition to the other. Engineers on the Mississippi River have the mission to maintain and improve navigation. Biologists are concerned with maintaining and improving the habitat for plant and animal life that flourishes in a river habitat. These two, seemingly different goals, can in fact, complement each other.

The St. Louis District Corps of Engineers has proved through their *Environmental River Engineering Project on the Mississippi* that they can improve navigation through the use of new, innovative river structures and also positively impact the biological environment.

The project began two decades ago when St. Louis Engineers began to look at existing navigation structures and analyze their ability to meet environmental as well as navigation goals. A team of biologists and river engineers was established to study the designs' effectiveness by measuring navigation improvement and the ability to improve habitat diversity. In addition, each design's cost effectiveness was measured against the cost of traditional structures.

APPLIED RIVER ENGINEERING CENTER

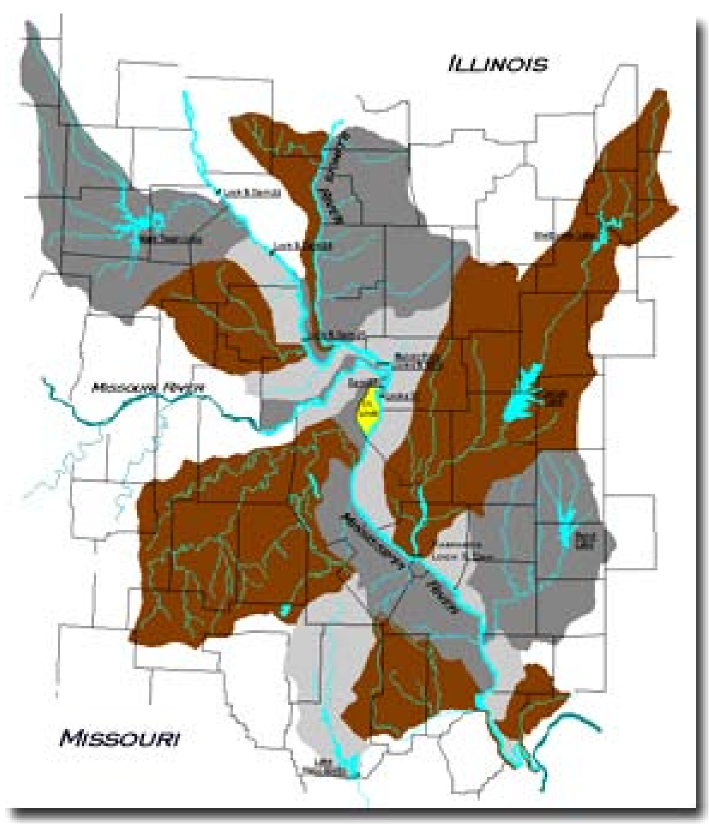
The result is a system of river structures that meet environmental, navigation and economic goals. The *Environmental River Engineering Project on the Mississippi* has been used as a model in other Corps districts. And, the structures resulting from this project are being used in other locations throughout the country.

Table of Contents

Geography

The Mississippi is over 2,220 miles long and has been in existence since before the last ice age. The Mississippi is the second longest river in the United States and the third largest river basin in the world, exceeded in size only by the watersheds of the Amazon and the Congo. All water between the Appalachian Mountains in the East and the Rocky Mountains in the West eventually flows into the Mississippi.

The Mississippi River Basin is a very large system, with watersheds draining 1,245,000 square miles. The central portion is known as the Middle Mississippi, defined as a 300 mile reach from Saverton, Missouri to Cairo, Illinois. St. Louis, Missouri is located about halfway between these two points. Further defining the Middle Mississippi are the confluences of three major tributaries, The Illinois River, The Missouri River and The Ohio River.



" ...steamboats on the Mississippi all burn wood, and such are the immense quantities destroyed in this manner that had not nature provided an inexhaustible supply, some other fuel would have had long since to take its place."

- Henry Lewis, a traveler, 1848 Mississippi River

History

The natural state of the Middle Mississippi River is narrow and deep. In the early 1800s, forests of trees spread out across the rich alluvial bottomlands and lined the river's banks. The river was so narrow that settlers could stand on the bank at Cahokia, and shout across to the settlement at St. Louis for a boat to come and ferry them across.

The Louisiana Purchase in 1803 marked the opening of the West. Settlements along the Mississippi like St. Louis began growing. In 1817, the first steamboat arrived in St. Louis, the Zebulon M. Pike. The population of St. Louis soared, and steamboat arrivals followed suit. From three arrivals in 1817 to more than 3,600 arrivals in 1858, steamboats had turned the Mississippi into a superhighway.

The rich timber resources which lined the Mississippi's banks were used to build rapidly expanding settlements, cleared for agricultural purposes and steamboats, as well as used to fuel the steamers' voracious boilers. As the steamboats and settlements grew, great forests of timber were cleared.

As the timber vanished, the river banks became less stable and rapidly deteriorated. The river widened and the less stable banks crumbled and fell. Trees were thrust into the river impeding navigation, and the congestion of the river traffic combined to make navigation difficult and steamboat travel dangerous. Many lives and vessels were lost.

Role of the River Engineer

"…the military engineers have taken upon their shoulders the job of making the Mississippi over again-a job transcended in size by only the original job of creating it."

- Mark Twain from Life on the Mississippi

The condition of the river had reached disastrous proportions. To correct the situation, Congress, in 1880, directed the Corps of Engineers to create and maintain a safe and dependable navigation channel and return the river to its once majestic condition.

The river engineers had to begin a bold plan to reverse man's destruction. This effort was begun by stabilizing the river banks and designing navigation structures that worked in harmony with the natural laws of the river.

A variety of methods and navigational structures were employed. River banks were stabilized, dredges removed sediment from the channel, and snag boats were used to clear downed trees, wrecked steamboats, and other debris.

'…To construct the stream according to conditions imposed or assumed can be done successfully if we know all the facts and relations which enter into the problem. The omission of one may be fatal to success; hence all arbitrary changes are to be avoided. But nature overlooks nothing and we may confidently assume that the position and direction of the river at any time is the resultant of all the forces, and consequently, is a concrete expression of the law of the stream, which we may modify and preserve, but may not safely destroy or radically change."

- Colonel James H. Simpson, 1875

The Problems:
Meandering River Channel

The Mississippi likes to meander as it travels south. This meandering creates havoc with the navigation channel which the Corps must maintain at a nine foot depth.

The river likes to cut new channels in areas where it makes sharp twists and turns. In places where the current hits a protruding river bank, it begins to wear down the exposed bank, eventually forming a side channel and later a main channel.

The Problems:
Eroding Banklines

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

The Problems:
Sedimentation/ Navigation Concerns


September 1934


October 1934


March 1936


October 1939

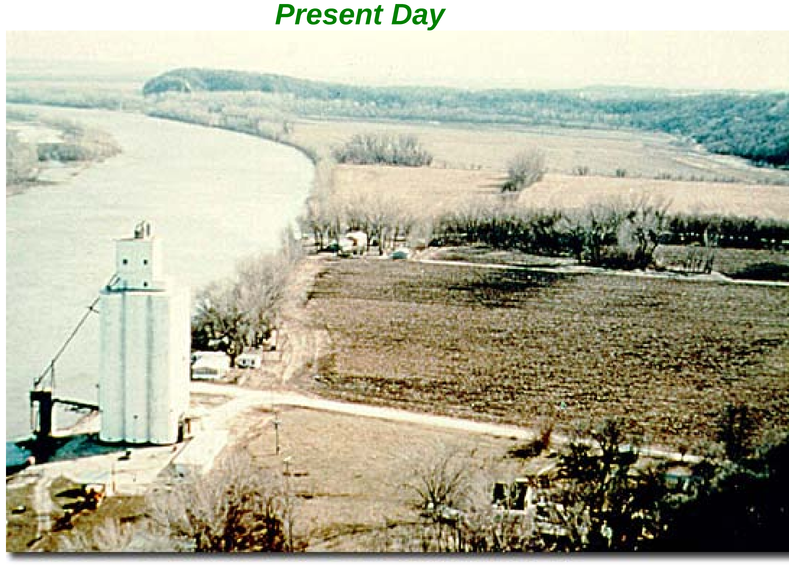

September 1956

Each year the Mississippi carries approximately 130 million tons of sediment to the Gulf of Mexico. That which doesn't reach the Gulf adds approximately 300 yards to the State of Louisiana each year. The rest is deposited in the river channel. How much and where depends on the speed of the river and the size and placement of the object impeding its flow.

Sediment diminishes the river by destroying aquatic life. Biological diversity is best achieved with a variety of river habitats including slow water and wetted edge, often found along banklines. Historically, the use of dikes and the resulting sediment build up assisted in narrowing and improving the channel. This is no longer desirable as this process takes away from the river's natural state.

These photos, all taken at the same location over a period of 50 years, show the results of the results of the gradual accumulation of sediment.

Present Day



The Problems:
Sedimentation/ Biological Concerns

Even without the use of dikes, sedimentation is a naturally occurring phenomenon. Traditionally, it was managed through the use of dredging. Disposing of the dredge material in an appropriate manner can also negatively impact the environment.

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

The Problems:
Homogeneous Environments

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

The Problems:
Narrowing of Channel Widths in River Bends

Since the late 1800s, when revetment and stabilization work began, the river has found ways to challenge man's ability to harness it tremendous energy.

Because the lateral erosion or meandering movement of the river has been held in check by these stabilization methods, the river has responded by diverting its lateral energy downward. This has caused a significant deepening of the river bends.

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

The Problems:
Navigation Impacts of River Bends

Groundings have historically occurred in bends as far back as the days of steamboats. Groundings are dangerous to both crew members and passing tows. They result in loss of time and money, and may be environmentally hazardous.

From 1985 to 1988, in the reach of river from St. Louis, MO to Cairo, IL, there was an average of 20 groundings per year that occurred in the bends. Many of these accidents were a result of the barges running aground on the point bars or crashing into the outside riverbanks. Some accidents were catastrophic to the environment, spilling oil and cargo into the river channel.

The narrow bends enabled only one tow to navigate the bend at a time. This created huge bottlenecks which cost time and money to the industry and ultimately the customer. In 1988, an investigation revealed that the costs associated with time delays in bends reached $24 million.

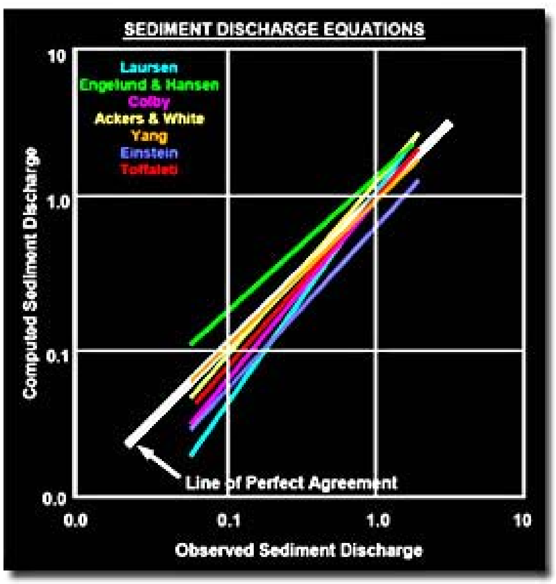
The formation of ice in the river can jam in the narrow bends completely blocking the navigation channel and forming massive ice dams. When breached, the ice flow may damage and destroy everything in its path.

The Problems:
Environmental Impacts of River Bends

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

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

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



Einstein's Bed Load Equation

$$\phi = \frac{q_B}{\gamma_S}\left[\frac{\rho}{\rho_S - \rho}\frac{1}{gd^3}\right]^{\frac{1}{2}}$$

The Problems:
Environmental River Modeling

In the late nineteenth and early twentieth centuries, river engineers usually relied upon intuition, experimentation, and trial and error processes to design river training structures. Successful projects were hailed as engineering marvels while unsuccessful projects remained to be solved at additional cost. Many of these projects caused long term effects to the river environment and wildlife habitat. Today, in some cases, engineers are tasked with correcting the negative environmental effects of those real life experiments.

There has never been a simple set of equations or rules to follow when it comes to analyzing moving water and sediment. Hans Einstein, son of Albert Einstein, developed equations for scientists and engineers to use in solving sedimentation problems on rivers and streams. He cautioned, however, that his equations were based only upon experimental data, and therefore could not be applied in all situations. Many other notable scientists have also developed experimentally based approaches, equations and methodologies to address sedimentation. Discrepancies, conflicts, and general unreliability are common. In all probability, no other engineering discipline has involved such a vast disparity between theory and practice!

One tool that engineers used in the past and still use today is a large physical sediment transport model. These models are typically enormous in scale, some nearly the size of a normal football field. They are built to resemble an actual river or stream and contain running water and moving sediment. Engineers have used these large models since the early 1950s to solve major sedimentation problems.

Unfortunately, the cost of building, operating, and housing these models is exorbitant and the time required to obtain results can take years. These two factors are the primary reasons why the widespread use of large models is impractical for most engineering projects. Most modeling practices have not allowed the involvement of biologists, environmentalists, etc. when designing structures and solving sediment related problems.

The Objectives:
Primary Habitats

"…The more species in a biological community the healthier the system appears to be. The greater number of species, the greater opportunity for interaction which creates more energy pathways and produces a stronger system. Without diversity, the system will collapse."

- Butch Atwood, Fishery Biologist,
Illinois Department of Natural Resources

Primary Habitats

There are four primary habitats which are important to a river ecosystem. They include:

Fast Water:
Water moving quickly, usually the current in the main river channel.

Slow Water/ Quiet Water:
Water outside of the main river channel moving slower than the primary river current.

Wetted Edge:
Land which is constantly getting wet and then dry again as the river rises and falls. This area is in a continual state of change. This habitat is very important as there is a constant exchange of nutrients from the land to the aquatic environment.

Terrestrial:
Land. Land separated from the shore is especially important because it is away from man and other predators.

The Corps developed a plan to solve the problems, defined its objectives, and established a team approach. The solutions to improve the biological diversity of the Middle Mississippi River had to be congruent with the Corps' directive to maintain a safe and dependable navigation channel. The solutions also had to be cost-effective.

The plan was to look at each of the navigation structures on the Middle Mississippi and analyze their biological impact. Then, address structural modifications which could make this impact more positive while maintaining the structure's navigation effectiveness.

Since these were separate and dissimilar goals, a team of biologists from the Missouri Conservation Department, the Illinois Conservation Department, the U.S. Fish and Wildlife Service and river engineers was formed to collect data before and after modifications and analyze the results of each project.

There are many factors that contribute to a river's navigability as well as species diversity. The one factor that the Corps could impact was habitat. The objectives focused on introducing these four habitat through design modifications of navigation structure.

The Solutions

Just as there is no one problem, there is no one solution. The Middle Mississippi is a dynamic and fast-changing stretch of river. The Northern half (mile 300 to 184) contains locks and dams while the lower half (mile 184 to 0) is open river. Each changing condition on the river creates the need for different solutions. Each solution, in its place, creates the opportunity for a diversity of habitats.

From the start of the inquiry, the Middle Mississippi was studied as an entire river system where different structures were designed to fit specific locations on the river. Each structure was evaluated as to its ability to improve biological habitat and meet navigation goals, within the entire reach of the river.

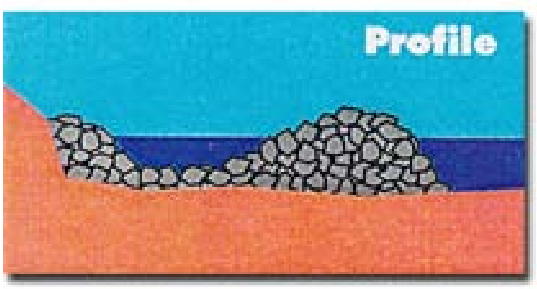
Before being installed in the river, many newly designed structures were model tested using either traditional large models or new HSR Modeling technology. Model testing evaluates various alterations and allows engineers to try nontraditional design approaches without the cost risks associated with field testing.

Once the structure is in place and its navigation effectiveness evaluated, a team of biologists assesses its environmental effectiveness by analyzing the number of species found at each structure.

Primary structural designs include:

- Notched Dikes
- Stepped-Up Dikes
- Revetments
- Off Bankline Revetments
- Chevron Dikes
- Side Channel Improvements
- Bendway Weirs

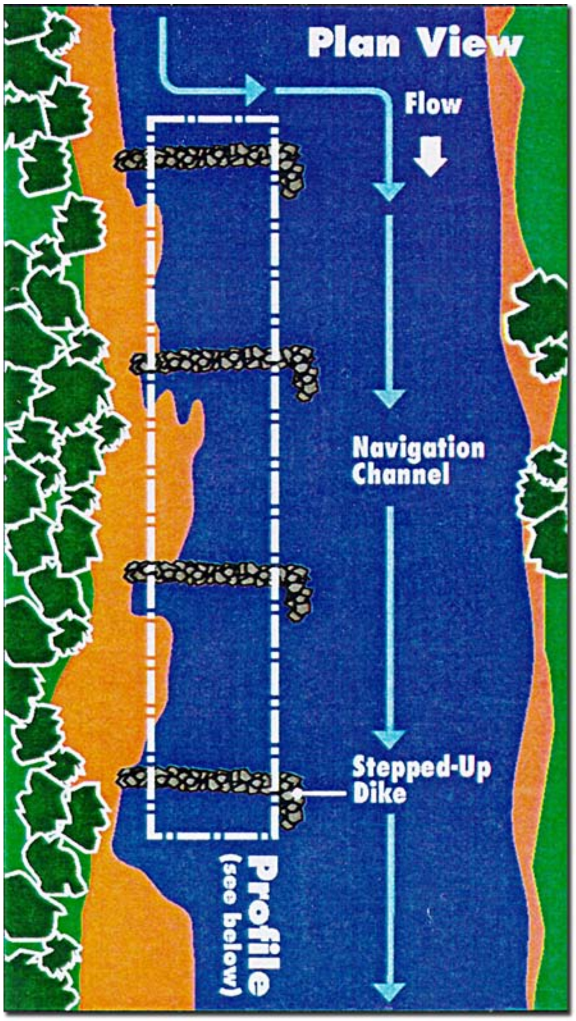
The Solutions:
Notched Dikes



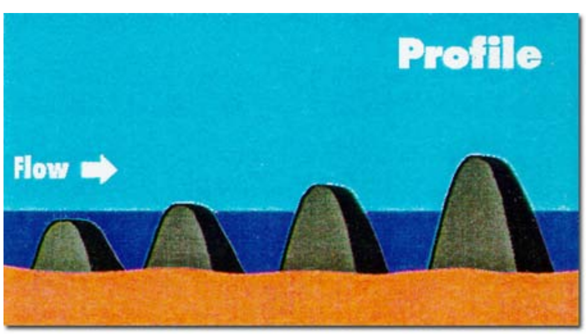
Rock dikes, running perpendicular to the shore, have long been used to guide the river and maintain the navigation channel. River engineers found that simply by adding notches, the dikes continue to create navigation dimensions as well as support diverse habitats. The river is allowed to move in and out between the notches creating all four of the primary river habitats. Sediment buildup forms small sandbars between each of the dikes. A variety of notch locations, sizes and widths were studied to create the optimum design. The overall result, however, is the creation of diverse environments by making a small but significant design modification. (Drawing illustrates environments)

The Solutions:
Stepped-Up Dikes

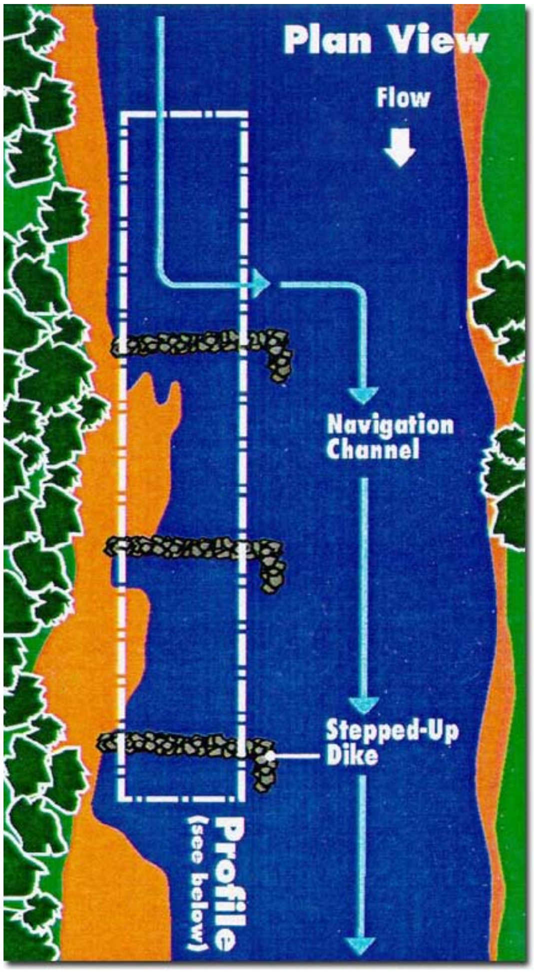
1.



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



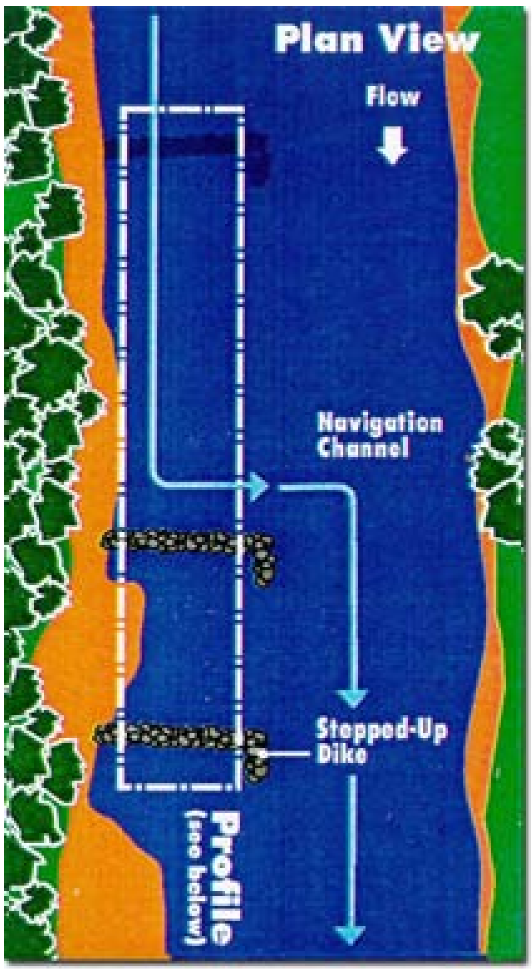
2.



THE SOLUTIONS:
STEPPED-UP DIKES

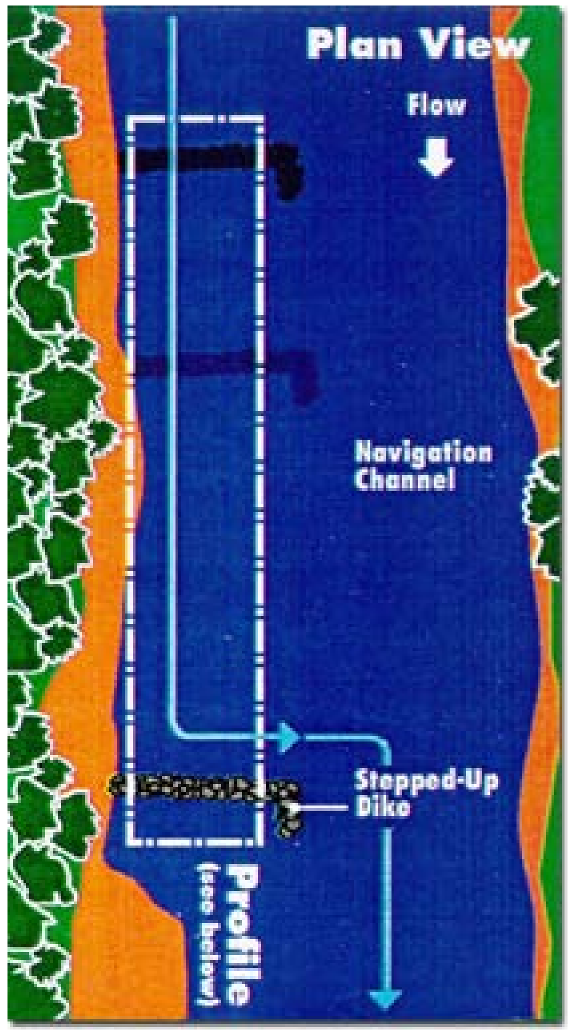
When the river's current hits the first dike it is propelled toward the main channel. As the river level rises, it moves over the first dike and hits the second dike, once again moving back into the main channel. This process repeats itself as the river rises and falls. The river's current, moving over each submerged dike, allows the sediment buildup to be redistributed back into the main channel and carried downstream. (Drawing illustrates environments)

3.

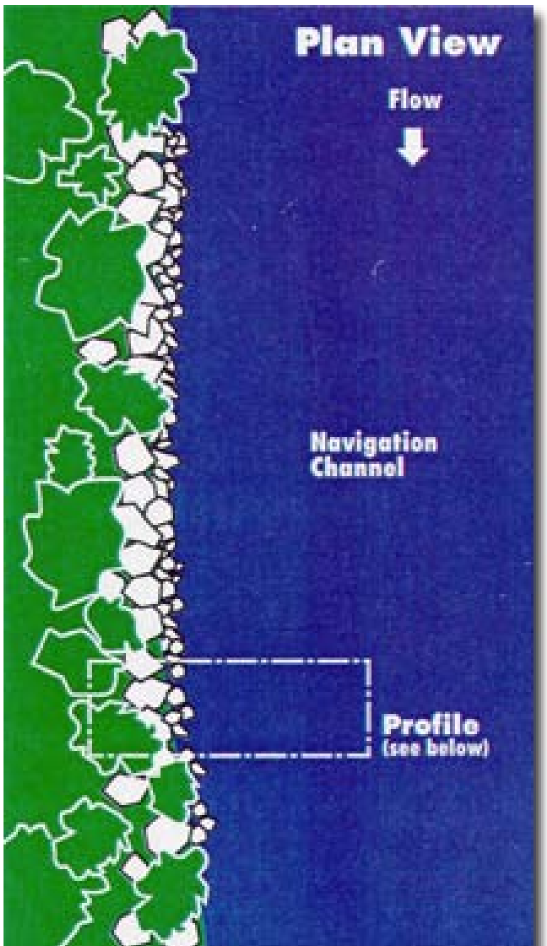


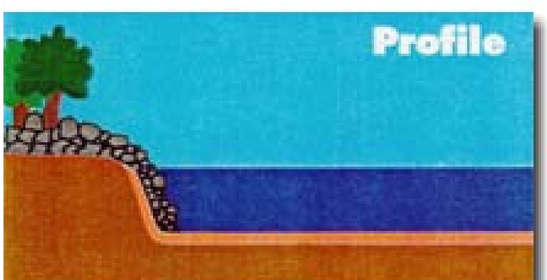
The Solutions:
Stepped-Up Dikes

4.



The Solutions:
Revetments



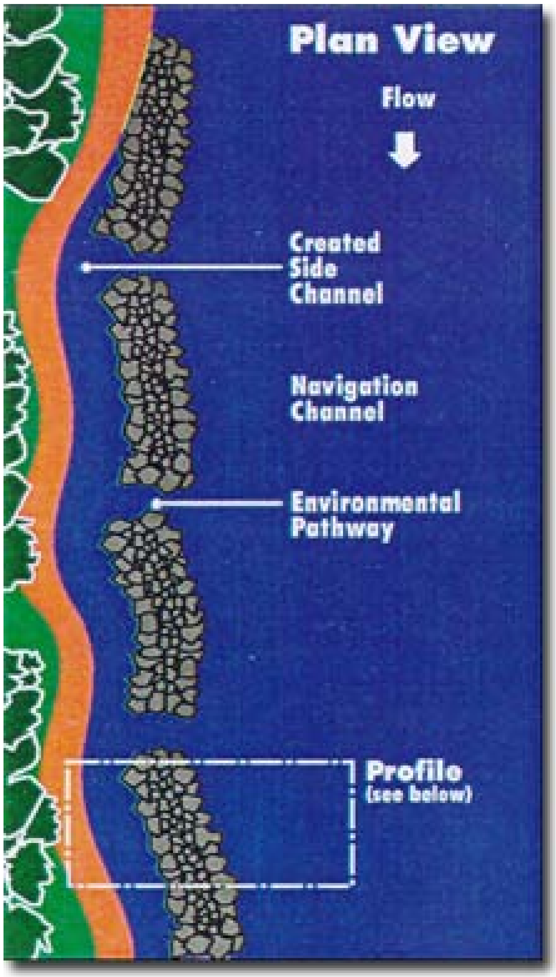


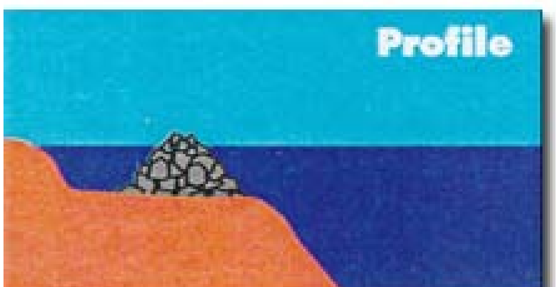
Traditional methods of stabilizing eroding riverbanks involved the removal of existing vegetation followed by grading the bank to form a stable slope on which to lay rock. The rock placed was relatively uniform with a maximum size of 400 pounds. The resulting environment was homogeneous and therefore did not provide for the same diversity as the natural river banks. (drawing illustrates environments).

The solution was found using a different gradation of rock with a maximum size of 5,000 pounds. This change provided two important benefits. First, the larger maximum size rock provided greater bank stability. This removed the requirement to grade the bankline and remove all the vegetation. For the first time, trees and rock revetment could coexist.

The second benefit was the wider variation in rock 20 size. The variety created with this gradation provided greater habitat diversity. In fact, it attracted more aquatic species than the natural caving bankline.

THE SOLUTIONS:
OFF BANKLINE REVETMENTS

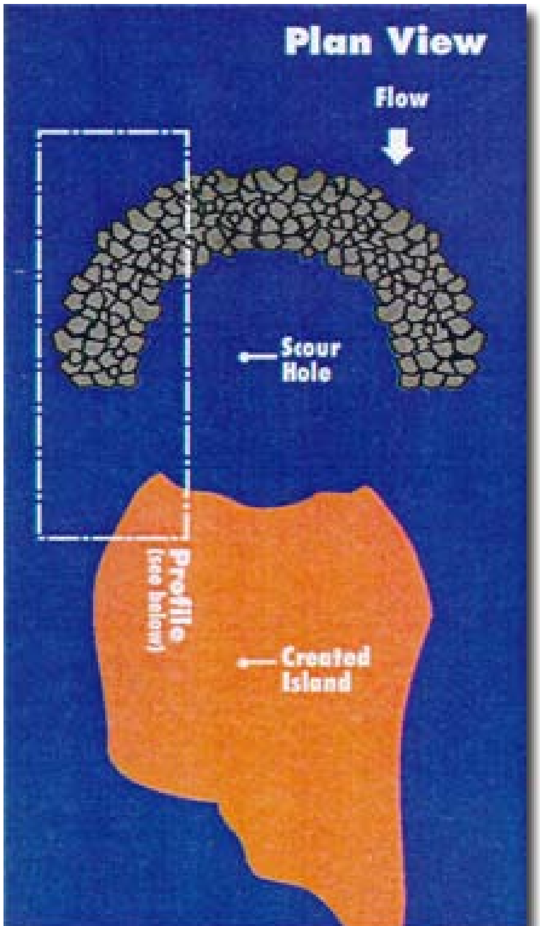




In areas where the caving river bank is on the shallow side of the river, there is a greater flexibility to design alternative solutions.

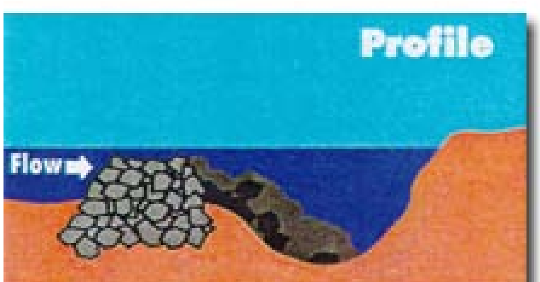
By placing a parallel structure of stone off the bankline, erosion is reduced and diverse habitats are maintained. In some areas, the revetment is notched allowing fish to move between the fast water and the slow water easily. The areas between the revetments and the bank line are considered to be prime fishing locations by both commercial and recreational fishermen. (Drawing illustrates environments).

The Solutions:
Chevron Dikes

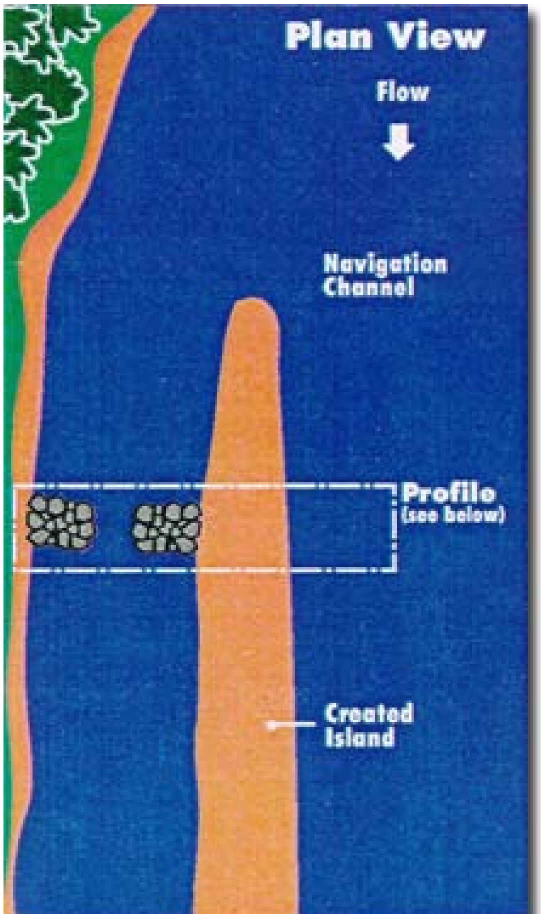


A navigation structure called a chevron dike was developed to improve river habitat and to create beneficial uses of dredge material. These structures are placed in the shallow side of the river channel pointing upstream. Their effect is to improve the river channel.

When dredging is needed to improve the main navigation channel, dredge sediment is deposited behind the chevron dike. These small islands encourage the development of all four primary river ecosystem habitats. In addition, various microorganisms cling to the underwater rock structures, providing a food source for fish. (Drawing illustrates environments).

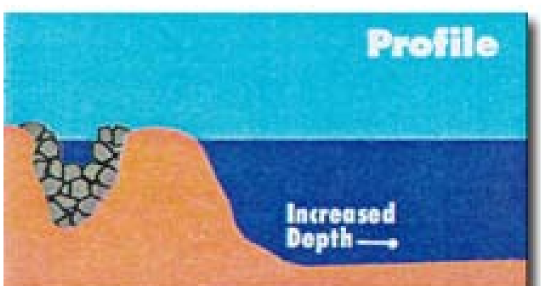


The Solutions:
Notched Closure Structures

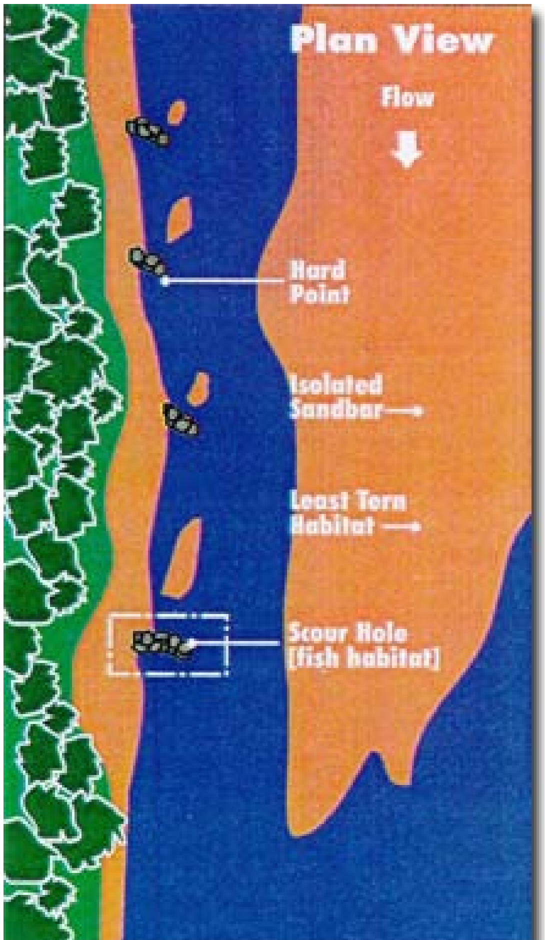


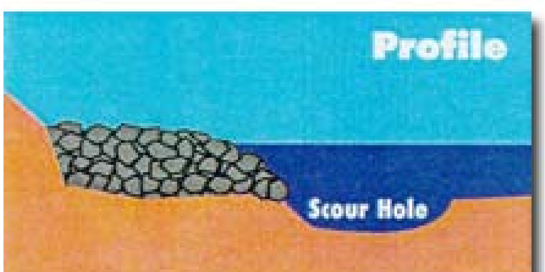
Side Channels are not used for navigation, but are valuable environmental areas. Traditionally, these side channels were closed with rock structures to divert the flow into the main channel. While improving navigation, this process tends to fill the side channels with sediment and convert aquatic habitat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

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



The Solutions:
Hard Points in Side Channels

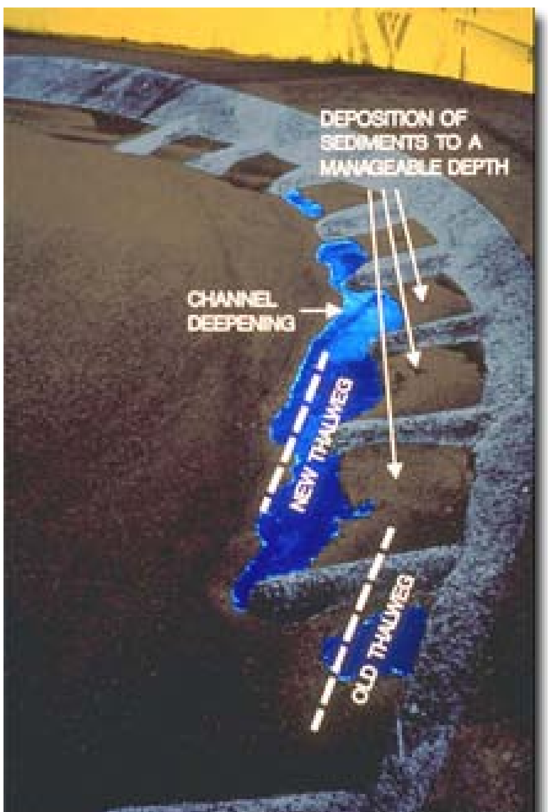


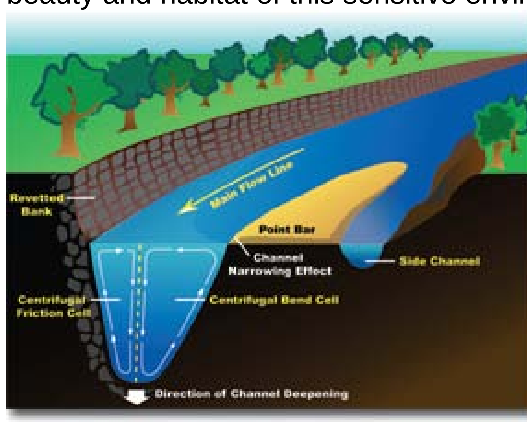


Hard points are very short rock dikes that are used to stabilize side channel river banks. These navigation structures extend from the riverbank into the river and do not cause a significant buildup of sediment. Their contribution to habitat improvement is the creation of scour holes under the hard points. These deep plunge holes attract catfish that flourish in this environment. (Drawing illustrates environments)

The Solutions:
Bendway Weirs

What is a Bendway Weir? The Bendway Weir is a low level, totally submerged rock structure that is positioned from the outside bankline of the riverbend and angled upstream toward the flow. These underwater structures extend directly into the navigation channel underneath passing tows. Their unique position and alignment alter the river's spiraling, secondary currents in a manner which shifts the currents away from the outside bankline. This controls excessive channel deepening and reduces adjacent riverbank erosion on the outside bendway. Because excessive river depths are controlled, the opposite side of the riverbank is widened naturally. This results in a wider and safer navigation channel through the bend without the need for periodic maintenance dredging. The Bendway Weir also eliminates the need for dikes to be constructed on the inside of the bendway therefore protecting the natural beauty and habitat of this sensitive environment.





The Solutions:
Hydraulic Sediment Response (HSR) modeling

Hydraulic Sediment Response (HSR) modeling is extremely small scale physical sediment transport modeling. The technology was developed by the Corps of Engineers for use in studying the Mississippi River. Engineers are now able to replicate the mechanics of an actual river or stream on an area the size of a normal table top. Since the HSR Model is much smaller than a typical large model, this presents the possibility of widespread usage by engineers around the country. The miniature scale not only allows significantly greater speed and accuracy by which solutions to problems can be achieved, but drastically reduces the cost of a typical sedimentation study. This enables the opportunity to incorporate environmental design into engineering design solutions. Environmental problems that would not have been modeled on a large scale in the past may now are modeled on a micro scale. Unreliable and complex equations, construction experiments in the river, and large expensive models are now things of the past. Today, any river or stream can be replicated and studied with amazing simplicity.

Using HSR Modeling technology, an innovative engineering or biological design can be model tested, evaluated, and constructed in the actual river or stream within a few short months. Such progressive, high speed design and construction is unprecedented in the field of river engineering.

APPLIED RIVER ENGINEERING CENTER

Micro controlled automation combined with highly accurate measurement devices are the keys to this technology. The hydraulic processes of a river or stream under study are replicated by employing a series of integrated process control valves, centrifugal pumps, micro level measurement gauges, and customized computer hardware and software. These devices allow the engineer to automatically control the flow of water and sediment through the model. The engineer is then able to allow the natural, complex hydraulic principals of moving water and sediment develop a duplicate bed form of the actual river in the HSR Model. A high resolution three-dimensional laser scanner is then employed to collect bed topography data on the HSR Model.

The Results:
True Environmental Engineering

The Missouri Department of Conservation tested the diversity in habitats surrounding a test section of notched dikes. Their raw data showed a total of 4,512 fish and 45 different species. After studying the data, they found an increase in diversity and numbers of micro-invertebrates. To a lesser degree, fish communities were also found to have greater diversity. In addition, the larger problem of aquatic environment becoming terrestrial was resolved. The river channel is maintained, structures are basically self-maintained and biological diversity has increased.

Tests by the Illinois Department of Conservation studying habitat diversity surrounding bankline and off bankline revetments showed the use of larger rock provided habitat for a greater number of fish than either small stone revetment or the natural river bank.

Isolated sandbars created by the various navigational structures provide nesting sites for the endangered Least Tern. These sandbars are away from man's encroachment which helps aid their development. In addition, the easy access from slow water to fast water provides valuable spawning ground for the endangered Pallid Sturgeon.

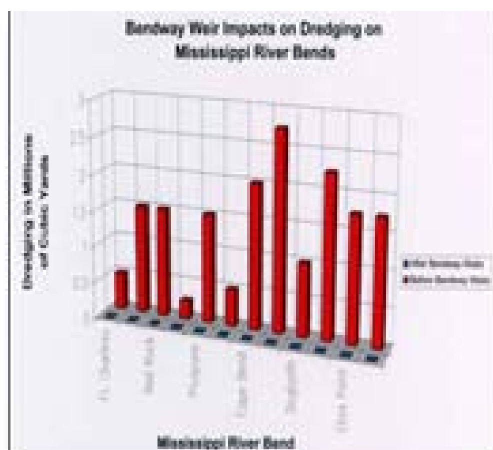
Each structure is a piece of a giant jigsaw puzzle, having to "fit" exactly to create a safe and dependable navigation channel and at the same time, stimulate the river's biological diversity.
Innovative concepts will continue to be designed and evaluated as the river engineers proceed with the environmental river engineering project: to work in harmony with the natural laws of the river.

The Results:
Bendway Weirs

The Bendway Weirs have not only provided navigation benefits, but many significant environmental benefits have been achieved as well. A wider and more smoothly aligned navigation channel has resulted so that traditional above-water dikes will no longer be built on the sandbars. Nesting Habitat for the Least Tern, an endangered bird species, is thus left largely undisturbed. Bendway Weir fields have also proven to provide habitat for a number of fish species. These environmental reefs have created diversity in the river bed and flow patterns in areas that were once narrow, deep, and swift. Monitoring efforts have shown that the federally endangered Pallid Sturgeon uses the weir fields significantly for their habitat.

Sampling shows fish love bendway weirs

In bendways where accidents and dredging were frequent, significant reductions have been made. Therefore, destructive impacts to the environment 28 caused by tow boat accidents and dredging have nearly been eliminated. The Bendway Weirs have also contributed to the reduction of excessive bankline erosion and overbank scour in some areas. Because the weirs are located below the water surface and never seen, the scenic beauty of the natural river is preserved.



The Results:
HSR Models

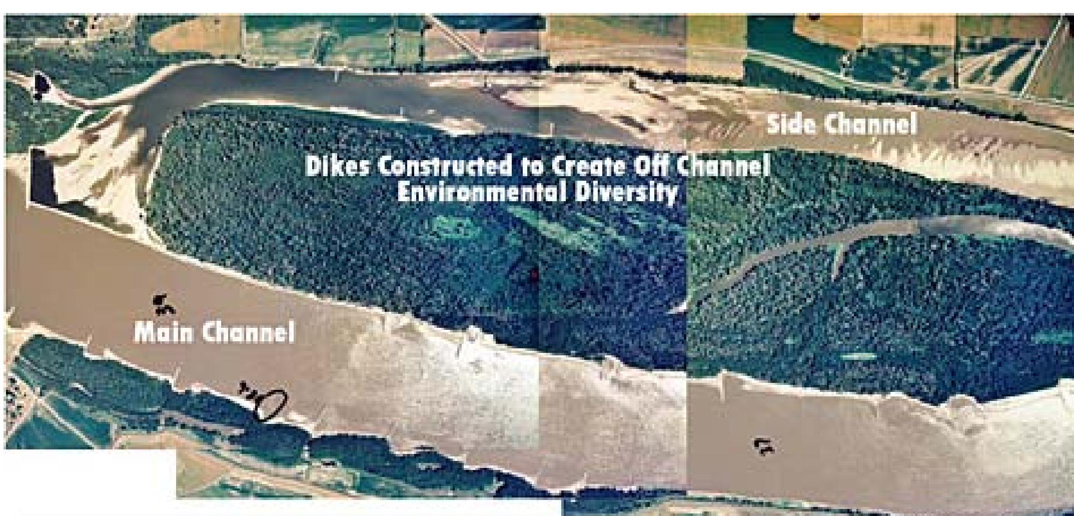
The Hydraulic Sediment Response (HSR Model) is an excellent environmental engineering tool. HSR Models have addressed environmental issues on a number of Middle Mississippi River side channels. The use of models has resulted in preservation and creation of habitat for fish and wildlife. HSR Models have also been used to study methods to alleviate costly and harmful dredging, to modify river training structures for habitat creation, and to protect pristine environmental areas. The models have been used in conjunction with several biological impact studies to examine endangered species, including the Pallid Sturgeon and the Least Tern.

Numerous environmental projects have been implemented as a result of the use of HSR Models. These include the environmental enhancement of several Mississippi River side channels and improvements to sediment and flow conditions on the Mississippi River. Several other projects are currently being designed or studied.

One of the greatest advantages provided by a HSR Model is the ability to convey highly complex hydraulic concepts to non-technical, non-engineering clients and partners.
This allows various river and stream partners to participate in the discussions, solutions, and designs. For the first time in history, a device exists that enables multifaceted interest groups to work together toward a single goal.

"The Hydraulic Sediment Response Models enable one to see and understand the interaction of large reaches of a river, and also gain a keen understanding of how upstream changes can adversely or positively influence downstream conditions several miles away."

- *Butch Atwood, Fisheries Biologist, Illinois Department of Natural Resources*



The Costs

The Mississippi is an ever-changing, dynamic river. The constant evaluation, the continual monitoring and the flexibility to react to the river's mood, requires continual updating of the project. The costs associated with the implementation of the *Environmental River Engineering Project* are inseparable from the channel improvement program and all design modifications have been incorporated into the program. The costs of coordinating with various interest groups, agencies, etc., are considered a part of the design process.

As a result of this environmental engineering project, significant environmental habitats have been created which have increased the diversity of the riverine environment at no additional cost to the channel improvement program or the American Taxpayer. What value can be placed on creating a healthy ecosystem?

- Endangered Species have been provided with increased nesting and spawning habitat, away from man's interference.
- Greater diversity can be measured in the number of habitats available and in the number of species occupying these environments.
- River engineering designs have achieved environmental and economic goals in a cost-effective, self-sustaining manner.

The Future

The process of improving the biological diversity of the Middle Mississippi while maintaining its use as a navigation resource is ongoing. New problem areas on the Mississippi will appear, each one requiring a different solution. Notched dikes continue to be studied to determine the best location, width and depth of the notch. In addition, the role of river levels and their affect on navigation and biological systems is being studied.

The Future:
Applications

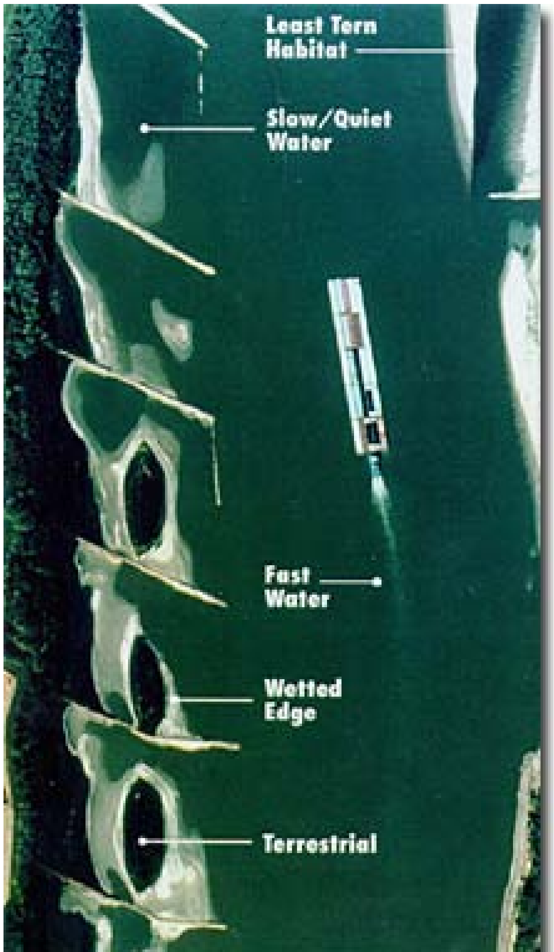
The environmental structures on the Middle Mississippi River are being used as models for similar structures on the Upper Mississippi as well as on other rivers. More importantly, the partnership between the river biologists and river engineers has set a new standard of achievement and cooperation. Similar teams and testing methods are being patterned after the St. Louis partnership in other Corps districts across the country.

It is the recognition and respect of each other's concerns and priorities that has fostered the cooperation and built the framework for the design and implementation of these environmentally sensitive structures.

"There was a time when Conservation was off on our own mission and the Corps was off on their own mission and we were not communicating with each other. Opening the lines of communication between the two agencies helps us both achieve our mutual goals. This open communication is, in many respects, our greatest achievement."

- Norm Stuckey, Fishery Biologist,
Missouri Department of Conservation

THE CONCLUSION



Navigation structures that work in harmony with the river have always been a priority. By developing a greater understanding of the need for habitat diversity through partnerships with river biologists, river engineers are able to design structures that afford an even greater harmony with the natural laws of the river without compromising navigation effectiveness. It's a situation in which everyone wins—man, nature and the river.

"…nature overlooks nothing and we may confidently assume that the position and direction of the river at any time is the resultant of all the forces, and consequently, is a concrete expression of the law of the stream, which we may modify and preserve, but not safely destroy or radically change."

- Colonel James H. Simpson, 1875

The Conclusion
Awards

Bendway Weirs have won numerous awards for the environmental and navigational benefits they have provided. These awards include the 1990 Permanent International Association of Navigation Congresses Gustave Willems Award, the 1991 Chief of Engineers Design and Environmental Awards Program's Award of Excellence, the 1992 American Society of Civil Engineers Award of Merit, and the 1992 Civilian Meritorious Award, and the 1995 Presidential Design Award.

In 1994, HSR Modeling received an innovation award from the St. Louis Academy of Science. In 1997, U.S. Patent Number 5653592 was granted to the U.S. Army Corps of Engineers for the HSR Modeling technology.

Articles

Atchison, Gary J., et. al., 1986. Aquatic Biota Associated with Channel Stabilization Structures andAbandoned Channels in the Middle Missouri River,Technical Report E-86-6, U.S. Army EngineerWaterways Experiment Station, Vicksburg, Mississippi.

Burch, Cary, et. al., 1984. Environmental Guidelines forDike Fields, Technical Report E-84-4, U.S. ArmyEngineer Waterways Experiment Station, Vicksburg,Mississippi.

Davinroy, Robert D., 1990. Bendway Weirs, A NewStructural Solution to Navigation Problems on theMississippi River, Permanent International Association ofNavigation Congresses, Bulletin No. 73, Osaka, Japan.

Davinroy, Robert D., Rapp, Jerry, and Myhre, Roger,1998. Hydrodynamic and Hydroacoustic Study of Fishesin Bendway Weir Fields of the Middle Mississippi River,American Society of Civil Engineers, WetlandsEngineering and River Restoration Conference, Denver,Colorado.

Davinroy, Robert D., Redington, Stephen L. and Strauser,Claude N., 1996. Design of Blunt Nosed Chevrons in theMississippi River for Sediment Management, SixthInteragency Sedimentation Conference, Las Vegas,Nevada.

Davinroy, Robert D., 1996. Micro Scale Physical Sediment Modeling (Micro Modeling) of Inland Henderson, Jim E. and F. Douglas Shields, Jr., 1984.Environmental Features for Streambank ProtectionProjects, Technical Report E-84-11, U.S. Army EngineerWaterways Experiment Station, Vicksburg, Mississippi.

Nunnally, Nelson R. and Linda B. Beverly, 1986. Morphologic Effects of Lower Mississippi River DikeFields, Miscellaneous Paper E-84-11, U.S. ArmyEngineerWaterways Experiment Station, Vicksburg, Mississippi.

Niemi, Jack R. and Strauser, Claude N., 1991. *"Environmental River Engineering,"* Permanent International Association of Navigation Congresses,Bulletin No. 73.

Polovina, Harry N., et. al., 1983. Evaluating Changes inDike Field Fishes with Community Information Indices,Technical Report E-83-14, U.S. Army EngineerWaterways Experiment Station, Vicksburg, Mississippi.

Smith, Roger H., et. al., 1982. The influence of Channel Regulating Structures on Fish and Wildlife Habitat, University of Missouri-Rolla, Institute of River Studies and Missouri Department of Conservation.

Way, Carl M., et. al., 1992. Effects of Surface Texture of Articulated Concrete Mattress Blocks on Their Habitat Value, Report 19, Lower Mississippi River Environmental Program, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

APPLIED RIVER ENGINEERING CENTER