DROUGHT, LOW WATER, AND DREDGING OF THE MIDDLE MISSISSIPPI RIVER IN 2012

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Abstract: In early 2012, low snowpack in the Rocky Mountains and the northern plains, followed by extreme heat, and prolonged drought in the plains and Midwest led to a long period of low water and record low stages on the Middle Mississippi River from June to February 2013. A drought of this magnitude had not occurred along the Mississippi River since 1988 and 1989. The U.S. Army Corps of Engineers (Corps) is responsible for maintaining a minimum 300 foot wide by nine-foot deep navigation channel. This task was especially challenging in 2012 as the drought carried on and conditions and forecasts worsened. However, due to strategic planning, engineering, and construction activities since the last major drought, the Corps was able to significantly lessen the impacts and provide a navigable channel throughout the drought and low water period through a combination of river engineering, dredging, forecasting, monitoring, and communication.

Although the Corps worked around the clock and seven days a week to dredge the channel, the amount of sediment that was dredged from the river channel was less than half of what needed to be dredged during the previous drought year. This is despite the fact that the number of low water days was more than in 1988/89 and the channel was dredged to greater depths in 2012. This paper will discuss what led to the significant improvement in the navigation channel, which included increased reliability and lower maintenance.

INTRODUCTION

The St. Louis District Corps of Engineers is responsible for maintaining a safe and dependable navigation channel on approximately 300 miles of the Mississippi River between Saverton, Missouri and Cairo, Illinois. The southernmost 195 mile section of the Upper Mississippi River, located between the confluences of the Missouri River and the Ohio River, is often referred to as the Middle Mississippi River. The Middle Mississippi River is a critical link in the inland navigation system and vital to the nation's economy. It is the middle link that connects the Lower Mississippi River and Ohio River systems with the Upper Mississippi River, Illinois River, and Missouri River systems. The Middle Mississippi River is unique because it is an open river system while the Upper Mississippi, Illinois Rivers, and Ohio Rivers use locks and dams to supplement navigation depths. The Lower Mississippi River is also open river system but has a much greater discharge that naturally supplements navigation. Therefore, maintaining navigation depths on the Middle Mississippi River has always been a significant challenge for river engineers. Engineers typically use a combination of river training structures, revetments, and maintenance dredging to keep the minimum nine-foot deep navigation depth year round.

While always a challenge, maintaining the navigation channel was made far more difficult in the fall and winter of 2012 due to extreme drought conditions in the Mississippi River watershed

(Figure 1). The drought was equal to or worse than any drought experienced in the past five decades. Water levels in the Middle Mississippi River reached near record lows, which posed a significant risk to commercial navigation traffic due to shallow channel crossings, reduced channel widths, and rock pinnacles located along the channel bottom (Figure 2).

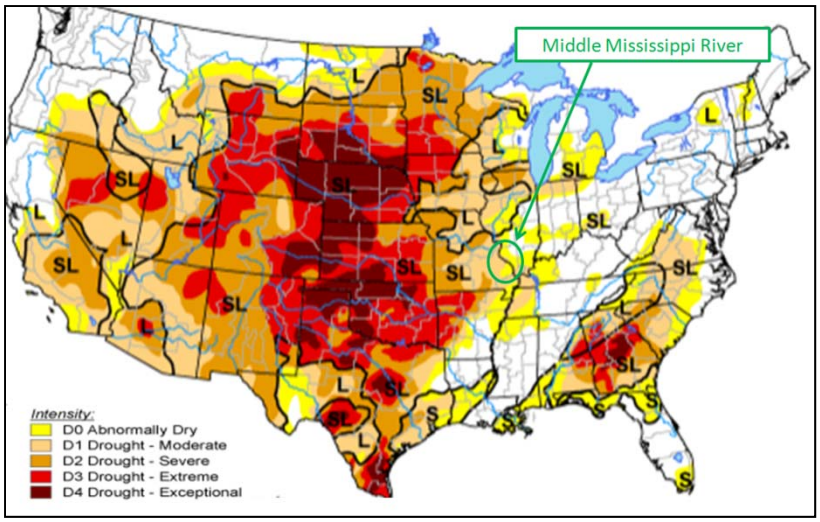

Figure 1. U.S. Drought Monitor map on January 1, 2013. (http://droughtmonitor.unl.edu/)

Figure 2. Drought and low water on the Middle Mississippi River meant exposed sandbars, hazards for navigation, and a narrow navigation channel.

EARLY SIGNS OF DROUGHT IN SPRING 2012

As early as April 2012 river engineers, water control managers, and the dredging team began preparing their staffs and upper management for the possibility of drought and probable low

water which would occur in the summer, fall, and winter of 2012. The weather in spring 2012 produced very little rainfall throughout the Midwest U.S. on top of a low snowpack in the Rockies and the plains, therefore the Mississippi River was much lower than normal for typical spring conditions. A flood level of 30 feet on the St. Louis gage is typically reached at least once during the spring rainy season, with a combination of inflows from the Upper Mississippi, Missouri, and Illinois basins. However, in 2012 the St. Louis gage only approached 20 feet briefly on just two occasions, in late March and again in early May. Otherwise, the stage remained well below normal throughout the spring and by early June was already ten feet below average. The river stages in 2012 were following a similar pattern to the stages early in the 1988/89 drought (Figure 3).

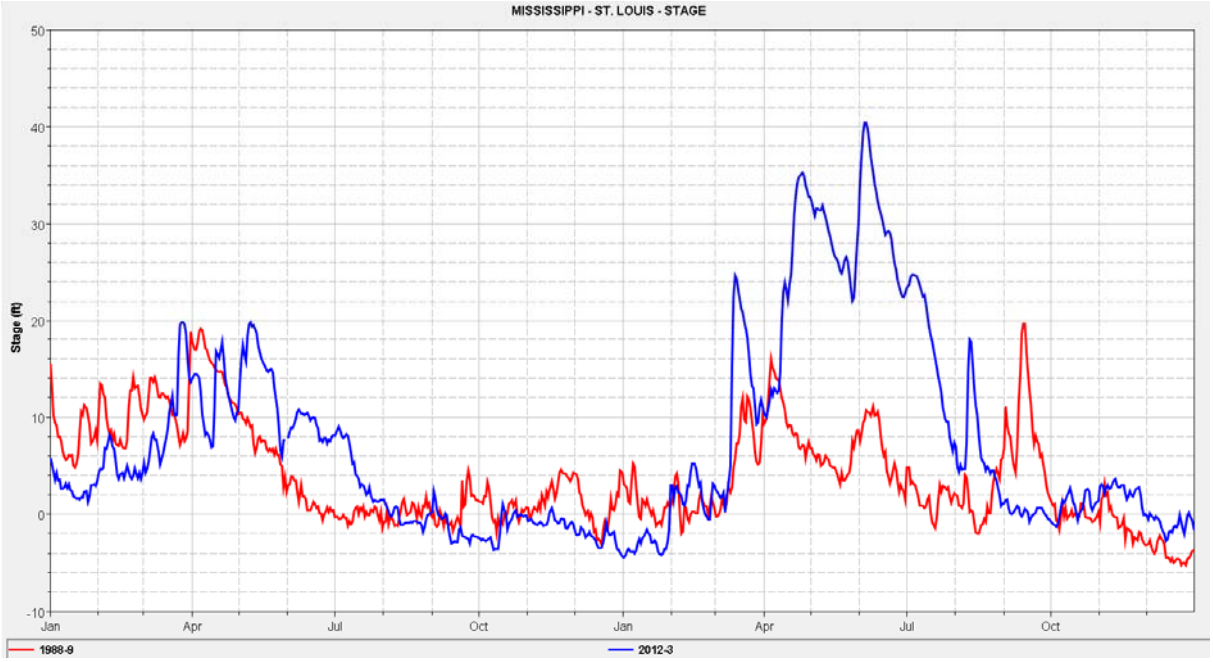

Figure 3. River stages at the St. Louis Gage over a 2-year period comparing 1988/89 with 2012/13.

The St. Louis District began communicating these conditions to the Corps Mississippi Valley Division (MVD) Office, River Industry Action Committee (RIAC), the River Industry Executive Task Force (RIETF), the United States Coast Guard (USCG), National Weather Service (NWS), and the United States Fish and Wildlife Service (USFWS). The teams discussed communication strategies, water management, forecasting, navigation channel monitoring, dredging capability, rock removal from the navigation channel, and various action levels/plans.

The team decided to start monitoring the navigation channel for trouble spots much earlier than a normal year. Channel reconnaissance surveys and pre-dredge surveys were collected early and often. The USCG Cutters and the Corps MV Pathfinder began patrolling the channel and resetting the channel marking buoys weekly. The St. Louis Harbor became narrow and congested as fleets encroached upon the navigation channel (Figure 4).

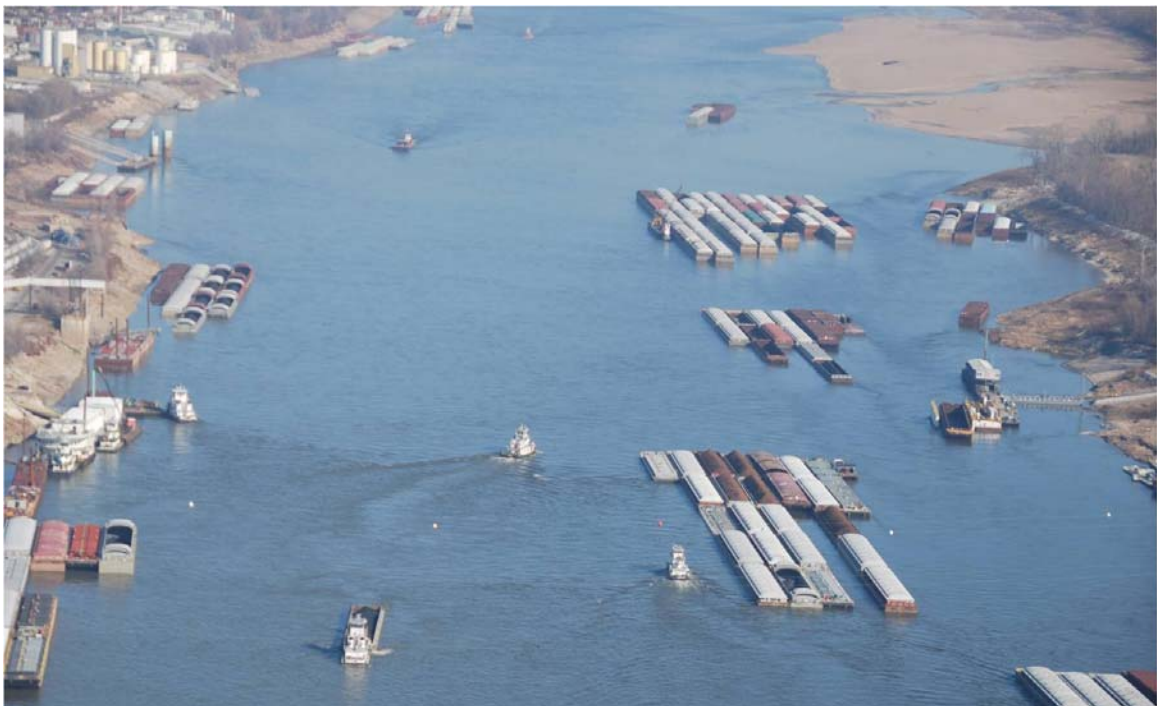

Figure 4. Low water conditions in the St. Louis Harbor meant that space for fleeting operations was limited.

DROUGHT RESULTS IN RECORD LOW WATER

Just as the Corps predicted in the spring of 2012, the drought took hold of the Midwest throughout an extremely hot summer. A sustained period of low water occurred on the Middle Mississippi River from June 2012 through the beginning of February 2013. The lowest stage at St. Louis during the low water period occurred in January 2013. A stage of -4.6 feet tied for the 7th lowest on record and was the lowest river had been since the drought of 1988/89 (Table 1). The length of the time the river remained at extreme low stages was also a concern. A stage of 0 feet on the St. Louis Gage is typically used by the Corps, the USCG, and the navigation industry to indicate low water and trigger additional action. The river stayed below 0 feet at St. Louis for 160 days during this period. By comparison, the river was below 0 feet for just 94 days in 1988 and 112 days in 1989. River engineers know that the longer the River stays below 0 feet, the more "lazy" it becomes as velocities and sediment carrying capacity declines. This results in more sediment accumulating in problematic reaches causing more problems for river industry.

Dredging during the low water event proved to be a significant challenge. Dredging operations began in early July 2012 and continued through February 2013 (Figure 5). The dredging team worked to prioritize dredging locations based on dredge efficiency and channel depths. Channel depths were continuously monitored through extensive channel patrol surveys. On typical years, the channel is dredged in order to maintain navigation depths 9 feet below a St. Louis stage of -3.5. Based upon forecasts for the fall and winter of 2012, the team decided to prepare the channel for a stage of -5.5 feet instead. Later in the year, when forecasts predicted that stages could be below -6.0 feet, the team decided to prepare the channel for a stage of -7.0 feet. This

new channel design was also predicated on the ongoing removal of rock pinnacles that were in the channel near Thebes and Grand Tower Illinois that would also allow depths to -7.0 when completely removed in January 2013 under an Urgent and Compelling Contract.

Rank	St. Louis Stage	Month/Year
1	-6.2	Jan 1940
2	-5.8	Jan 1963
3	-5.6	Jan 1964
4	-5.5	Dec 1937
5	-5.4	Dec 1989
6	-4.8	Jan 1957
7	-4.6	Jan 1956
	-4.6	Jan 2013
9	-4.5	Jan 2003
10	-4.3	Dec 1933

Table 1. A ranking of the lowest daily stages recorded at the St. Louis, Missouri river gage.

Figure 5. The Dredge Potter moves to the side to allow a tow to pass in September 2012.

The complexity and significance of the rock removal component of the mission cannot be overstated. This work required integrated and coordinated management along with the application of innovative technology and tools / removal methodologies. Risks associated with barge tow collisions with rock pinnacles were high, from both a fiscal and an environmental perspective. Current and future river construction contract needs were adjusted in order to fund the rock removal project. River engineering projects were reprioritized to allow for detailed plans and specifications to be produced to accommodate a tight project schedule. Removal of

the pinnacles involved advanced surveying techniques coupled with innovative removal methodologies. Work locations within the rock removal areas were prioritized to get the most dangerous (highest elevation) rock out first, with a secondary focus on providing optimal channel widths.

Water managers constantly collected water data, monitoring a number of hydrological and meteorological factors to forecast river conditions the rest of the low water team relied upon. Continuous monitoring of flows from the Middle Mississippi River tributaries and associated impacts played an important role in decision making. In close coordination with USCG and NWS, water managers operated Mel Price Locks and Dam, just upstream of St. Louis, under a deviation with a higher pool to alleviate impacts of water level fluctuations through the St. Louis Harbor. During the most critical water levels, the managers also utilized water in Carlyle Lake to augment flows for navigation purposes over the lower section of the Middle Mississippi River in order to temporarily increase stages.

Throughout the entire low water period, the District coordinated with project stakeholders including (but not limited to) RIAC, RIETF, the USCG, the NWS, and USFWS. The task of keeping the Middle Mississippi River open to commercial navigation is highly visible, politically sensitive, and extremely complex. Therefore, the district maintained close coordination of their activities with MVD, the Corps Headquarters Office in Washington D.C., the Assistant Secretary of the Army's (ASA) Office, the Department of Homeland Security and the White House. This required sending daily updates and information to all entities regarding: compliance with all relevant environmental regulations (National Environmental Policy Act (NEPA) and Fish and Wildlife Coordination Act (FWCA)); management of pool and reservoir elevations; forecasted river levels; status of the removal of the underwater rock pinnacles; dredging activities, including shoal locations; and providing a nearly continuous flow of channel and rock pinnacle surveys.
As a result of these activities during this low water event there were no accidents, groundings or unplanned closures of the Middle Mississippi River. This performance was unprecedented given that a similar drought in the late 1980's featured numerous groundings, accidents, channel closures, restrictions and a generally unreliable channel.

THE MIDDLE MISSISSIPPI RIVER NAVIGATION CHANNEL, NOW AND THEN

Accurate records of groundings during the 1988/89 drought are not readily available. However, according to newspaper articles, there were 22 groundings in just one weekend in December 1989 which caused the USCG to essentially close the entire Middle Mississippi River until conditions improved. By comparison, throughout the entire 2012/13 low water event there were no groundings or unplanned closures within the marked navigation channel. Some barges went aground on a few occasions, but in each situation it was determined that the tow had grounded outside of the marked channel.

What is the difference between the channel in 1988/89 and the one today? Following the drought of 1988/89 the St. Louis District embarked upon an aggressive river engineering project that resulted in the development, design and construction of innovative structures such as bendway weirs and chevrons that have significantly reduced channel maintenance dredging and resulted in a much more reliable channel during the 2012 drought. The Regulating Works

Project utilized innovative techniques to redesign the navigation channel which has led to the development of new types of river training structures.

Bendway Weirs were developed in the early 1990's as a means to improve navigation around the tight bends that are typical along the Middle Mississippi River. The development of these structures has been revolutionary for river engineers and the navigation industry. Over 175 bendway weirs have been constructed on this part of the River which has resulted in a significant reduction in the dredging of point bars and the elimination of accidents through these bends.

River engineers in the St. Louis District realized that for the project to be sustainable they had to adjust their design techniques and parameters in order incorporate environmental features into their navigation channel improvement projects. The engineers worked with closely with biologists in the Corps partnering agencies to develop different types of versatile structures in order to both protect the environment and to improve navigation. River training structures such as chevrons (Figure 6), off-set dikes, and W-dikes have successfully implemented by the river engineers in the St. Louis District. These types of structures have been shown to provide both navigation and environmental benefits.

Figure 6. Chevron river training structures near River Mile 32.

The St. Louis District also developed Hydraulic Sediment Response (HSR) models for use in the design of river training structures. After HSR models were fully developed, the District established the Applied River Engineering Center as a facility to conduct these physical models and other sediment studies of the Mississippi River and its tributaries. The use of the HSR models and AREC allowed the district to efficiently study and design multiple sets of river training structures that had both navigation and environmental benefits. The AREC facility has been used regularly to engage and collaborate with the environmental community during the entire design process. The technology has also allowed the engineers to be so efficient with the designs that the Project did not have enough capacity to implement the construction of these designs on a yearly basis. Therefore, many designs were put on the shelf to await funding.

When requests for projects eligible for the American Recovery and Reinvestment Act (ARRA) came about in 2009, the district was well positioned to act. Multiple river training projects qualified as "shovel-ready" and were funded by ARRA. The construction of these ARRA river training structures remedied many of the chronic dredging locations and led to a more reliable navigation channel.

Operational changes were also been undertaken to improve the district's responsiveness to low water events. A Project Delivery Team (PDT) consisting of elements from river engineering, water management, dredging, and surveying continue to meet weekly throughout the year to address river conditions in a timely manner. Outreach to both other government partners (USCG, NWS, etc.) and the river industry has led to a better understanding of, and response to, navigation concerns. A weekly channel status report is sent to the river industry and other invested partners. Internally, a river condition status report is generated weekly to anticipate dredging and surveying needs.

Surveying capabilities have also dramatically increased district responsiveness. Equipment improvements such as multi-beam sonar and increased surveying capacity utilizing two contract surveying companies have also led to an increased awareness of the state of the channel over the capabilities that were available in 1988/89. Survey data can now be sent directly from the boat to the office for post-processing and analysis leading to channel evaluations that can almost instantly be shared with the navigation industry.

Water management and forecasting have also greatly improved. Critical coordination occurred throughout the day and night with water managers upstream of St. Louis, including the Rock Island District for the Upper Mississippi and Illinois Rivers and the Northwest Division for the Missouri River. The St. Louis District constantly monitored inflows and adjusted the outflow at Mel Price Locks and Dam to alleviate impacts of water level fluctuations through the St. Louis Harbor. The District also utilized the available water in Carlyle Lake to augment flows for navigation purposes over lower portion of the Middle Mississippi River in order to temporarily increase stages by timing the releases as the water had to travel down the Kaskaskia River.

During low water, channel patrol efforts using the Corps M/V Pathfinder were increased to identify problem areas, replace or move buoys to better mark the narrowing channel. Assuring the channel is well marked prevents groundings which may further degrade the channel and defers dredging until a dredge can be assigned to that specific location. The USCG also increased their buoy tending runs. Schedules for the patrols between USACE and USCG are coordinated to maximize coverage on the system.

THE RESULTS OF THE RIVER ENGINEERING PROGRAM

In 1988 and 1989 alone, over 19 million cubic yards of material were dredged each year for a total of 38.1 million yards of material removed from the navigation channel. Compare that to the low water period of 2012/13 where only 9.3 million cubic yards of material were removed in just the one year. While the drought of 1988/89 encompassed two full dredging seasons and the drought of 2012/13 was only in one dredge season, the events can be compared considering that no two droughts are the same. Not only was significantly less material removed in 2012 by

comparing that year to either 1988 or 1989, but the channel was fully prepared for a stage of -7.0 at St. Louis, which was a full 3 feet lower than in 1988/89 (Table 2).

Dredge Season	Days below 0 ft at St. Louis	Dredge Volume (cubic yards)	9 ft Navigation Channel Prepared to a St. Louis Stage of:
1988	94	19,100,000	-4.0
1989	112	19,000,000	-4.0
2012/13	160	9,300,000	-7.0

Table 2. The period of low water and dredging volumes compared between the drought of 1988/89 and 2012/13.

The St. Louis District's river engineering program developed a ranking system of chronic dredging locations in order to prioritize the construction of river training structures. The system is based on a weighted average of the last 5 and 10 years of dredging in two mile river segments. The top ten dredging locations by volume in 1988/89 are shown in Table 3. The table shows the volume of material removed from these locations in 1988/89. The table also shows that the river engineering program has reduced the amount dredged from these locations by an average of 82%. The changes mentioned above highlight just a small portion of the changes that have occurred on the river in the last 25 years to reduce the number of lower water or confined channel dredging locations. Under multiple programs, over 175 bendway weirs were constructed since 1989 to widen the navigation channel and increase center channel depth. These same programs have funded multiple new dikes, chevrons, and other river training structures over the past 20 years to improve and maintain channel depth.

River Mile	1988-89 Rank	Dredged in 1988-89 (cy)	Current Rank	Dredged in 2012 (cy)	Percent Reduction
52 - 54	1	2,228,800	38	35,468	-98%
42 - 44	2	1,892,600	36	225,500	-88%
66 - 68	3	1,706,700	5	530,976	-69%
38 - 40	4	1,646,000	6	323,781	-80%
6 - 8	5	1,545,700	34	167,213	-89%
46 - 48	6	1,257,800	8	450,047	-64%
30 - 32	7	1,246,400	24	112,748	-91%
28 - 30	8	1,232,400	37	0	-100%
166 - 168	9	1,204,300	16	366,400	-70%
14 - 16	10	1,125,000	33	350,308	-69%

Table 3. The top ten ranked dredging locations in 1988/89 compared to 2012.

An analysis of the most troublesome dredging locations in 1988/89 compared to 2012 is even more dramatic. In 1988/89 the worst 20 miles of river accounted for over 15 million cubic yards of dredging over these two years. The worst dredging location for the 1988/89 time frame was the stretch of river from River Mile (RM) 54 to 52, near Cape Girardeau, Missouri. This stretch

was responsible for over 2.2 million cubic yards of dredging between 1988 and 1989. Since then, bendway weirs have been placed at the upstream extent of the stretch. In 2012, less than 36,000 yards were dredged in this reach for a 98% reduction.

The second-most dredged location in 1988/89 was between RM 44 and 42, near Thebes, Illinois. This reach of river required nearly 1.9 million cubic yards of dredging, with the dredging partially necessitated by the presence of submerged rock pinnacles that constrained the navigable channel. Since 1989, several additional dikes were constructed to better maintain flow alignment in the navigation channel. Efforts have also been made to remove the rock pinnacles to increase navigable channel width, both in 1989 and in 2012. In 2012, only 225,000 yards of material were dredged for a reduction of 88%.

The third-most dredged location was between RM 68 and 66, near Moccasin Springs, Missouri. In 1988/89, this area required over 1.7 million cubic yards of dredging. Dike extension was used in this reach to reduce dredging by 69% in 2012. Although this is a significant reduction, the reach still ranks currently as the 5th highest priority for work on the Middle Mississippi River based on dredging. To address the ranking, this stretch was recently studied with a HSR model with the principle goal of further alleviating the need for dredging. Construction of several innovative river training structures is scheduled for fiscal year 2016. The Project will not only reduce dredging in the main channel, but will add significant environmental enhancement in the form of a side channel or chute.

CONCLUSION

The nation's economy is heavily dependent upon the safe operation and reliability of the Middle Mississippi River corridor that transports 110 million tons per year or nearly $34 million worth of goods on a daily basis in and out of the St. Louis Harbor. Shut downs and delays to the river navigation industry can have profound effects on a regional and national level.

The entire 2012 low water effort resulted in a navigation channel that remained open for commerce throughout the drought, without any groundings or accidents within the channel, and generally led to a much more reliable channel for shippers. The implementation of a successful river engineering program led to the reduction in sediment and dredging volume as compared to a similar drought and low water period in 1988/89. Furthermore, improvements in hydraulic modeling, design of river training structures, water management techniques, bathymetric data collection, coordination with the towing industry and the Coast Guard, and the identification and removal of rock outcroppings from the riverbed can be also credited with the improvements.

This improvement in dredging was the result of an aggressive 20+ year long river engineering program that has reduced dredging costs and increased the safety and the reliability of the channel. The development and implementation of innovative river training structures, such as bendway weirs and chevrons, resulted in a much improved navigation channel while also creating diverse aquatic habitat.

In conclusion, the Middle Mississippi River Regulating Works Project since 1988/89 has resulted significant improvements to:

- Dredging – Significant reductions in the volume of dredge material resulting in a much lower Operations and Maintenance (O&M) cost.
- Depth – A river channel that can be maintained to deeper depths if needed, closer the authorized channel depth, for much less cost.
- Reliability – Shippers and carriers have much greater confidence in the ability of the River to carry goods when needed. This confidence means that more goods will be transported by the River every year that it can be demonstrated that the channel will be available full time and without delay.
- Safety – The 2012/13 low water period resulted in zero channel groundings and no incidents of hazardous chemicals spilled as a result of an accident.
- Habitat – The Middle Mississippi River contains more diverse aquatic habitat through the use of innovative river training structures such as chevrons, W-dikes, multiple round point structures, side channel enhancement dikes, and off-set dike extensions.