MISSISSIPPI RIVER COMMISSION

Protecting the Alluvial Empire:

The Mississippi River and Tributaries Project

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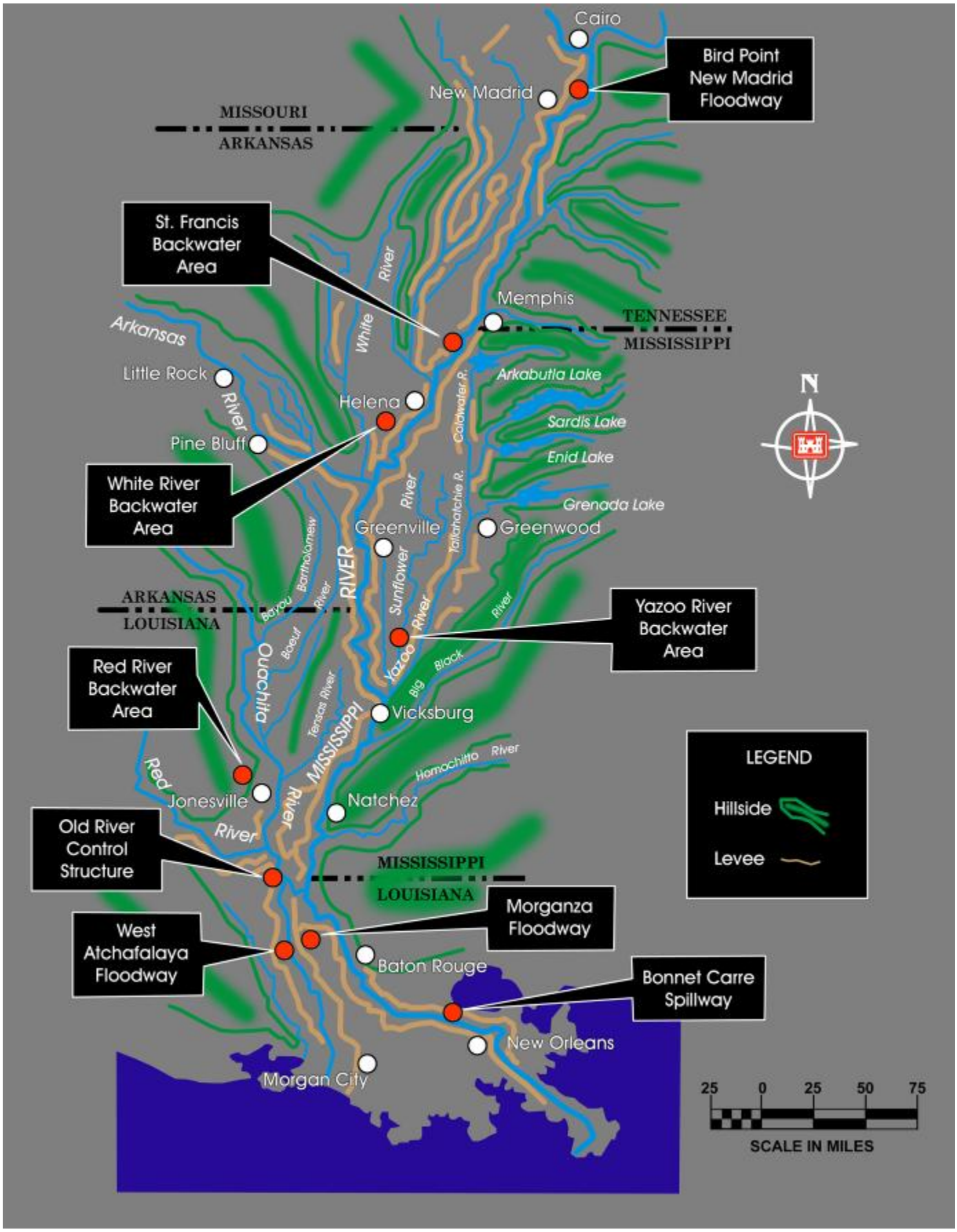
Cairo
Bird Point New Madrid Floodway
New Madrid
MISSOURI
ARKANSAS
St. Francis Backwater Area
Memphis
TENNESSEE
MISSISSIPPI
Arkansas
White
River
Little Rock
Arkabutla Lake
Helena
Coldwater R.
Sardis Lake
Pine Bluff
Enid Lake
White River Backwater Area
Grenada Lake
Greenville
Greenwood
Tallahatchie R.
Bartholomew
RIVER
Sunflower
ARKANSAS
LOUISIANA
Bayou
Boeuf
Yazoo River Backwater Area
Red River Backwater Area
Ouachita
Tensas River
Yazoo
Big
Black
Vicksburg
MISSISSIPPI
Homochitto River
Red
Jonesville
Natchez
River
Old River Control Structure
MISSISSIPPI
LOUISIANA
Morganza Floodway
West Atchafalaya Floodway
Baton Rouge
Bonnet Carre Spillway
New Orleans
Morgan City
N
LEGEND
Hillside
Levee
25 0 25 50 75
SCALE IN MILES

FOREWORD

The Manifestation of the Alluvial Empire

For centuries the alluvial valley of the Mississippi River captured the fanciful imagination of so many who recognized the vast untapped potential of a land of abundant riches. In his seminal study, *Alluvial Empire*, Robert W. Harrison traces colonial, local and state efforts to protect, reclaim and develop the lower Mississippi Valley. At the height of Old Imperialism, the French, and later the Spanish, saw the mighty river and the surrounding fertile lands as the lifeline of a vast commercial empire in the New World. After the Louisiana Purchase in 1803, American frontiersmen sought to facilitate trade and develop the region's riches, but soon discovered the advantages of the river came with considerable risk. Later, American farmers sought to supplement the productive antebellum cotton plantations by draining the great swath of swamp lands in the interior portion of the valley and exposing the "very dark brown, creamy and sweet-smelling" soil lying beneath. Reflecting the spirit of the New Imperial Age, they likened the valley to an "American Congo," an undeveloped "frontier of opportunity" from which great wealth could be extracted. Early 20th century entrepreneurs described the alluvial valley as a "New Eden in the heart of America."

As Harrison expertly points out, the successive generations of colonial settlers, American pioneers, farmers, capitalists and entrepreneurs each developed and implemented their own plans for realizing their vision for an Alluvial Empire. Each of those plans depended on levees, starting with the first levee constructed by the French near New Orleans in 1717, as a means of flood protection. Yet, every time the vision seemed within grasp, the river would take it all away without notice. Floods in 1753, 1844, 1858, 1882, 1884, 1890, 1897, 1912, 1913 and 1916, among others, interrupted the dream for an Alluvial Empire at varying stages of development. Still they continued on, undaunted. Then the Great Flood of 1927 seemingly shattered the dream forever.

The damages from the 1927 flood were staggering: more than 16.8 million acres of land flooded; up to 500 lives lost; 41,000 buildings destroyed; more than 160,000 homes rendered unlivable, creating up to 700,000 refugees. The flood was not merely one that impacted the valley, its consequences were felt nationwide as the raging waters severed east-west communications and commerce for months as more than the 3,000 miles of rail, thousands of miles of roads and highways, numerous bridges, telephone and telegraph poles were forced out of service. Some estimates place the total losses at $1 billion during an era when the federal budget rarely exceeded $3 billion. Such astounding impacts carry a hint of historical hyperbole, but even the head of the relief effort, Secretary of Commerce Herbert Hoover, described the Great Flood of 1927 as the "greatest peace-time calamity in the history" of the United States. Yet remarkably, instead of killing the vision for the Alluvial Empire or the New Eden in America, the Great Flood of 1927 served as the genesis for the comprehensive Mississippi River and Tributaries (MR&T) project, which is described in the pages that follow.

In light of the development that has taken place in the alluvial valley since the birth of the MR&T project in 1928, a repeat of the consequences of the 1927 flood and the impact on the national economy would be unfathomable. Today, the area flooded in1927 is home to nearly four million people living in a million households. It is also the site of more than 10.6 million acres of prime agricultural lands that produce revenues around $7 billion each year while providing more than 100,000 jobs, not to mention feeding the world. That same area flooded in 1927 is now home to scores of manufacturers that generate more than $100 billion in output and provide approximately 400,000 jobs; 12 major oil refineries with a combined capacity of nearly three million barrels per day, plus hundreds of thousands of oil and gas wells and related pipelines; more than 100 power plants, including three nuclear power plants, that account for more than 20 percent of the total power generated in the seven states comprising the alluvial valley. The area also has 3,600 miles of rail used by four major Class I freight carriers that

nationally had a combined $50 billion in operating revenues in 2011, as well as 5,100 miles of highways, including sections of five major interstates: I-10, I-20, I-40, I-55 and I-57. This infrastructure connects the manufactures, retailers, farmers and energy producers of the region to a vital commercial artery that has more than 30 ports in the former flooded area, including four of the nation's busiest ports in south Louisiana, and moves roughly 500 million tons of cargo annually. These figures do not account for the vast timber and mineral extraction industries or the world class tourism and outdoor recreation sectors that thrive in the area once devastated in 1927.

In the spring of 2011 a flood that rivaled and exceeded the Great Flood of 1927 at most locations on the Mississippi River between Cairo, Ill., to Baton Rouge, La., struck the lower Mississippi valley. Unlike in 1927, the 2011 flood did not cause similar staggering impacts to the aforementioned people and investment. In this regard, those who live, work and play along the river can accurately describe the success of the MR&T project in conveying the 2011 flood as the manifestation of the striking vision of our predecessors to transform the undeveloped alluvial valley into the long-elusive Alluvial Empire. We do so, however, absent any hubris as the history of flood control on the lower Mississippi is brimming with examples of the horrors of arrogance and complacency. We also do so with great trepidation for a lingering question persists: will the MR&T system perform as designed in the next, and inevitably even greater, flood event?

As the venerable project inches toward 2028, the 100-year anniversary of the MR&T, we must recognize that a massive flood greater than anything experienced before will surely surprise the nation in the future, possibly the near future. Ensuring that the MR&T project is prepared for that test and remains productive for generations is our requirement today. It will also serve as our legacy. As George Grugett, the legendary long-time Executive Vice-President of the Mississippi Valley Flood Control Association masterfully wrote in the foreward of *Divine Providence: The 2011 Flood in the Mississippi River and Tributaries Project*, the success of the MR&T project in conveying the 2011 flood "did not happen because of some overnight miracle." Grugett goes on to attribute the success to "the foresight of the people" that formed a triad consisting of the United States Congress, the Corps of Engineers and the local people that sought to solve the flood problem on the lower Mississippi River through the passage of the 1928 Flood Control Act and the creation of the MR&T project. The triad did not stop there, as they worked together to modify, expand and invest in the MR&T project for more than 80 years.

This unbelievable responsibility now rests with the current iteration of the triad. Will future generations look back on our generation with the same level of admiration? Will this generation invest in the future and take action to provide for the next generation, as our predecessors did for us? As the world-envied MR&T project gracefully approaches its 100th birthday, these questions inevitably will be answered and our legacies judged accordingly.

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[1] Robert W. Harrison, *Alluvial Empire* (Little Rock, Arkansas: Pioneer Press, 1961).

[2] William A. Percy, *Lanterns on the Levee* (Baton Rouge, Louisiana: Louisiana State University Press, 1941): 3

[3] Nan Elizabeth Woodruff, *American Congo: The African American Freedom Struggle in the Delta* (Cambridge, Massachusetts, 2003).

[4] Southern Alluvial Land Association, *The Call of the Alluvial Empire* (Memphis, Tennessee: 1919).

[5] These figures were taken from a variety of sources, including Industrial Economics, Inc., *Economic Profile of the Lower Mississippi River Region* (Cambridge, Massachusetts, 2004). This report states that in 1998 manufacturing generated $87 billion in revenues and provided 383,000 jobs. The $87 billion figure, when adjusted for inflation, amounts to approximately $126 billion in revenues in 2014; Association of American Railroads, *Class I Railroad Statistics*, April 17, 2013.The major Class I freight operators include Burlington Northern-Sante Fe Railroad ($19.6 billion), Kansas City Southern Railroad ($1.2 billion), Canadian National Railroad ($9.1 billion), and the Union Pacific Railroad ($19.5 billion); Oil and Gas Journal, *List of Oil Refineries in the United States*, 2014.

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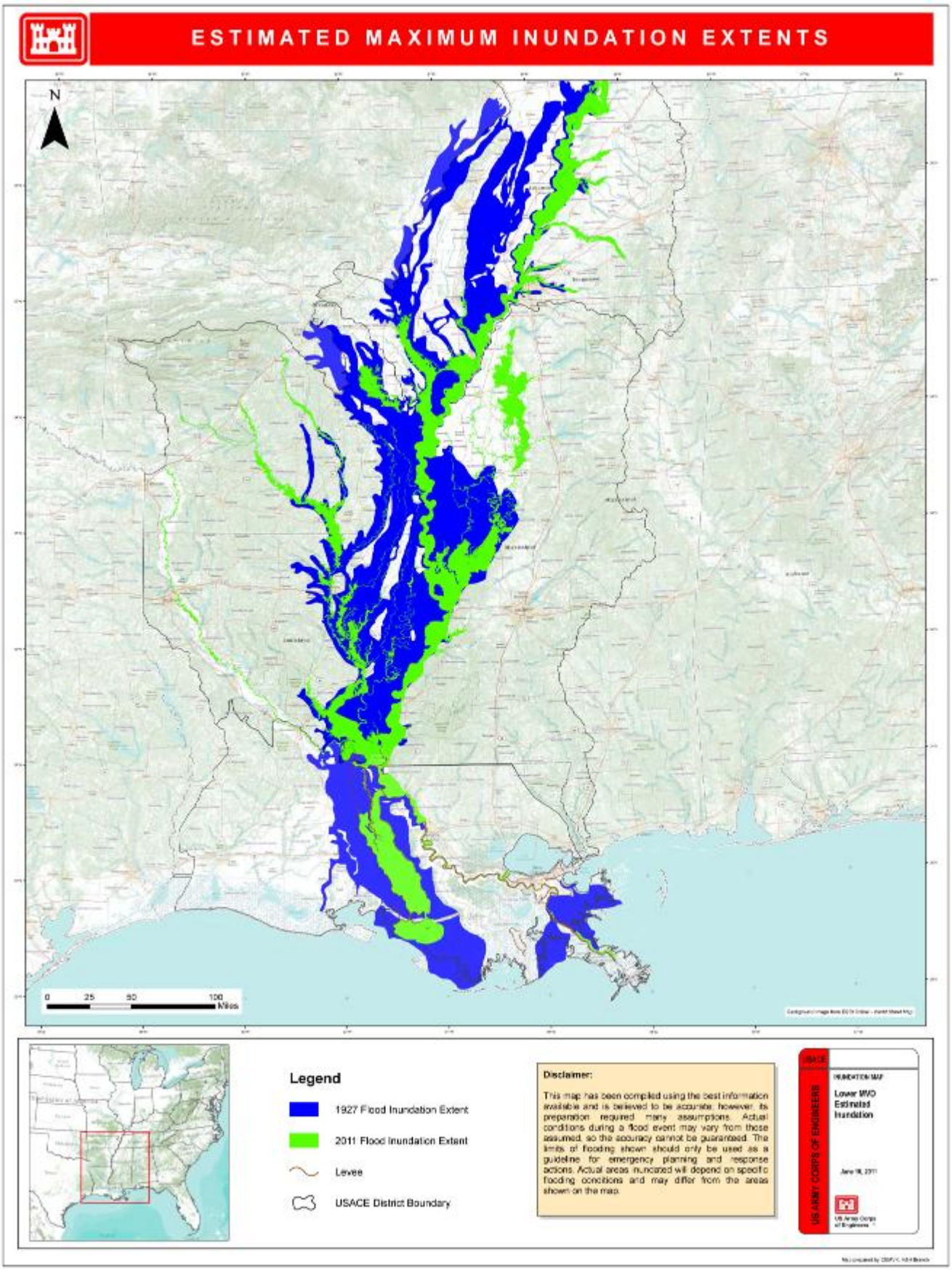

ESTIMATED MAXIMUM INUNDATION EXTENTS
N
0 25 50 100
Miles
Legend
1927 Flood Inundation Extent
2011 Flood Inundation Extent
Levee
USACE District Boundary
Disclaimer:
This map has been compiled using the best information available and is believed to be accurate; however, its preparation required many assumptions. Actual conditions during a flood event may vary from those assumed, so the accuracy cannot be guaranteed. The limits of flooding shown should only be used as a guideline for emergency planning and response actions. Actual areas inundated will depend on specific flooding conditions and may differ from the areas shown on the map.
US ARMY CORPS OF ENGINEERS
INUNDATION MAP
Lower MVD
Estimated
Inundation

The MR&T: A Wise Investment

The Great Flood of 1927 left the lower Mississippi Valley in shambles. The swollen river exerted unprecedented pressure on the region's prized, but outmatched, levee system. The unyielding pressure proved too great, causing the system to unravel through seventeen major federal levee crevasses and dozens more state and local levee breaches. As the massive flood overwhelmed the levees, it left a path of destruction up to eighty miles wide. The river inundated 16.8 million acres, killing hundreds and turning nearly 700,000 more into refugees. The flood also left commerce and communications severed, with millions of acres of prime farmland under water, critical infrastructure in more than 170 counties in seven states rendered unusable and thousands of businesses destroyed.

In the wake of such devastation, the nation galvanized its commitment to prevent a similar tragedy, leading to the authorization of the comprehensive Mississippi River and Tributaries (MR&T) flood control and navigation project through the landmark 1928 Flood Control Act. The record-setting 2011 flood severely tested the benefits of that commitment. Despite experiencing river discharges roughly 25 percent greater than those of the 1927 flood, the MR&T project protected 62 percent of the land flooded in 1927 from inundation. No lives were lost. Nearly one million households, along with critical infrastructure and major industrial, commercial and retail facilities that stood in harm's way, escaped the flood undamaged.

The astounding success demonstrated by the MR&T project reflects two majors changes in engineering policy instituted after the 1927 flood. Prior to that tragic flood event, the federal government, states and levee districts attempted to control floods on the lower Mississippi by building levees high enough to

Arkansas City, Ark., during the 1927 flood.

Arkansas City, Ark., protected by the MR&T system during the 2011 flood.

Opening of Morganza Floodway, May 14, 2011.

withstand the last great flood of record. Since the passage of the 1928 act, however, the comprehensive MR&T project has attempted to accommodate the natural tendency of the river to expand during floods by designing and implementing engineering features to control the greatest flood with a reasonable chance of occurring.

The MR&T project employs a variety of engineering techniques to provide enhanced flood protection to more than four million people living in the 22.4 million-acre project footprint, while maintaining a mutually compatible and efficient navigation channel. Those techniques include an extensive levee system, complete with relief wells and seepage berms, to prevent disastrous overflows from inundating developed lands; floodways and backwater areas to provide room for the river to expand; channel improvements and stabilization features to protect the integrity of structural flood control measures from scour and to ensure proper alignment and depth of the navigation channel; and tributary basin improvements in the form of drainage ditches, levees, headwater reservoirs, flood gates and pumping stations that maximize the benefits realized on the main stem by expanding flood protection coverage and improving drainage into adjacent areas within the alluvial valley.

Since the initiation of the MR&T project, the nation has contributed $14 billion toward project planning, construction, operation and maintenance. To date the nation has received a 44 to 1 return on that investment, including $612 billion in flood damages prevented since 1928. At the same time, waterborne commerce on the Mississippi River has increased from 30 million tons in 1940 to nearly 500 million tons today. Such astounding figures place the MR&T project among the most successful and cost-effective public works projects in the history of the United States.

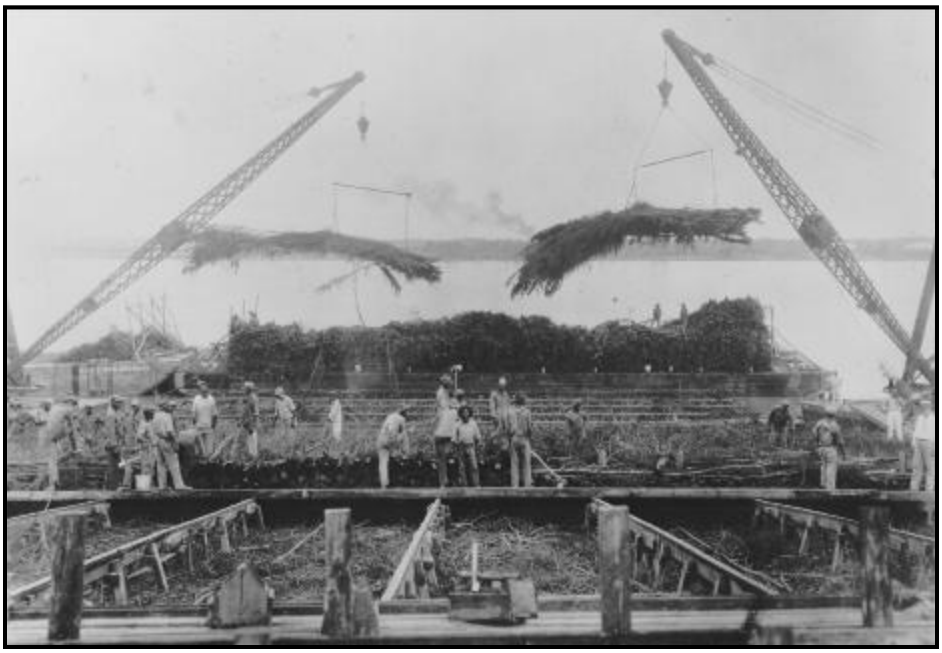
Mississippi River Commission

The MR&T project is administered by the Mississippi River Commission under the supervision of the Office of the Chief of Engineers. The commission has a proud heritage that dates back to June 28, 1879. Congress established the seven-member presidential commission and tasked it to transform the Mississippi River into a reliable commercial artery, while protecting adjacent towns and fertile agricultural lands from destructive floods. What had come to be known in engineering circles as "the Mississippi problem" represented the most difficult engineering endeavor ever undertaken by the federal government up to that time.

The excitement and allure of the complexities of the assignment attracted the leading hydraulic and civil engineers from around the country to join the commission or its staff. In short order, the Mississippi River Commission quickly assumed the role of an active federal agent capable of transcending the regional issues that had previously hampered the states and local authorities in developing a more effective river improvement system.

The commission conducted a survey of the river from its headwaters at Lake Itasca to the Head of Passes near its mouth and obtained reliable data for an accurate map that served as the basis for future surveys to ascertain changes in the dynamics of the river. The commission also began improving the navigation channel to promote commerce and setting standards for levee construction. In doing so, the commission made marked technological advancements in the field of hydraulic engineering, dredging, dike and levee construction, and revetment design and application.

The commission also began conducting inspection trips and public hearings at various points along the river. In that process of face-to-face interaction and open dialogue, the Mississippi River Commission evolved into a vehicle for local interests to have a greater voice in shaping federal policy. That long-standing tradition continues to this day through semi-annual high-water and low-water inspection trips conducted, respectively, each spring and summer. During the inspections, the commission listens to the concerns confronting the many entities charged with managing the Mississippi River and inspects the many challenges it poses. The commission then forges long-term partnerships to develop engineering solutions to those challenges.



Early bank protection using brush mattress.

The Mississippi River Commission combines the talents of the Army, the National Oceanic and Atmospheric Administration and the private sector.

The structure of the Mississippi River Commission consists of three U.S. Army Corps of Engineers general officers, three civilians, two of whom must be civil engineers, and one admiral from the National Oceanic and Atmospheric Administration (NOAA).

Each member is nominated and appointed by the President of the United States and vetted through the Senate. The commission president also serves as commanding officer of the Mississippi Valley Division.

The other military members typically serve as the commanding generals of the Corps of Engineers' division offices responsible for managing the key contributors of water to the Mississippi River, such as the Ohio, Missouri, Arkansas, White and Red rivers.

The civilian members, in turn, bring representation from the world's most innovative engineering and business pools of talent - the United States private sector.

Representation from NOAA, the science agency of the Department of Commerce, equips the commission with accurate weather forecasts, objective analyses of climate changes, unmatched mastery of marine sciences and state of the art LIDAR technology.

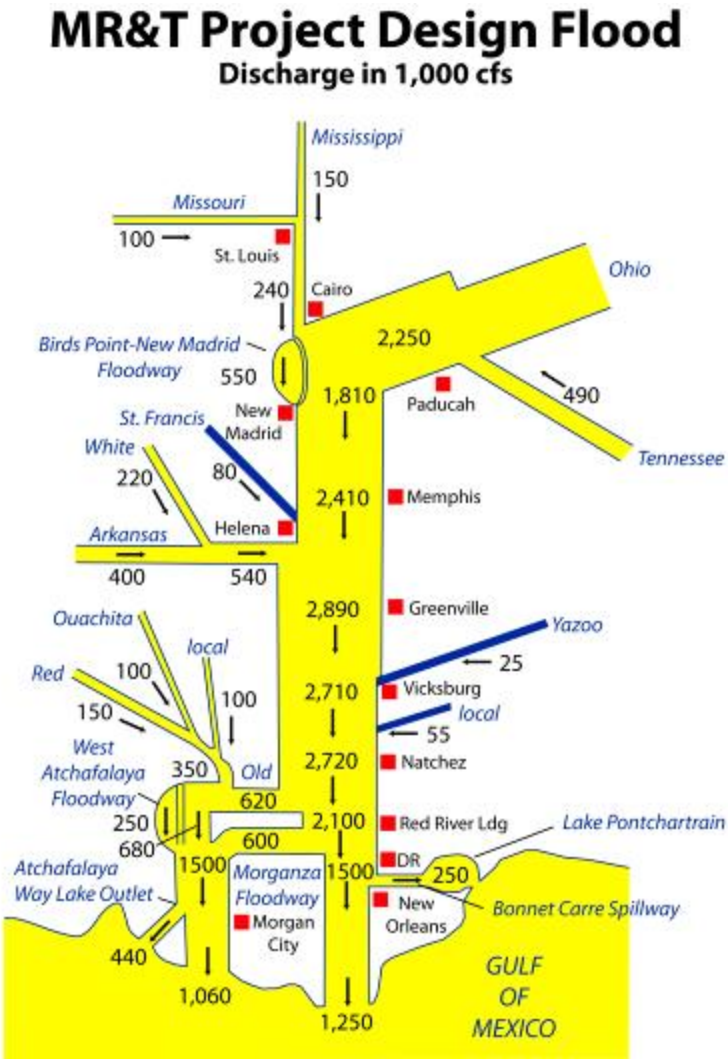
Understanding the Project Design Flood

The success of the MR&T flood control program can be attributed to the construction of engineering features to convey a project design flood rather than merely trying to protect against the last flood of record. The project design flood represented the worst probable scenario that meteorologists and hydraulic engineers could devise,

The original project design flood developed in the aftermath of the 1927 flood represented a combination of separate analyses conducted by the U.S. Weather Bureau (now the National Weather Service) and the Mississippi River Commission. For the most part, both analyses combined the maximum floods on the major tributaries, with all simultaneously contributing flows to produce the greatest possible effect at Cairo, Arkansas City and at the latitude of Red River Landing. The commission adopted a revised project design flood in 1941, following a second cooperative analysis with the Weather Bureau in the aftermath of the 1937 flood.

The Mississippi River Commission adopted the current project design flood in 1956, in response to a request by the Senate Committee on Works for a thorough examination of the MR&T project. The resultant study, again conducted in cooperation with the Weather Bureau, incorporated previously unavailable data regarding the sequence, severity and distribution of past major storms and investigated 35 different hypothetical combinations of actual storms that produced significant amounts of precipitation and runoff.

The Weather Bureau arranged the historical storms sequentially to mimic frontal movements and atmospheric situations that were consistent with those occurring naturally to determine the most feasible pattern capable of producing the greatest amount of runoff on the lower Mississippi River. This included the consideration of storm transpositions, storm intensity adjustments, seasonal variations and storm mechanics. In simpler terms, the Weather Bureau developed the project design storm series from various combinations of storms and resultant floods - referred to as



hypo floods - that had a reasonable probability of occurring from a meteorological viewpoint.

The studies revealed that Hypo-Flood 58A had the most probable chance of producing the greatest discharge on the lower Mississippi River from Cairo to the Gulf of Mexico. Three severe storms comprised Hypo-Flood 58A. The first is the storm of January 6-24, 1937, that struck the Ohio and lower Mississippi River basins, with rainfall increased by 10 percent.

It is followed three days later by the storm of January 3-16, 1950, over the same general area. This storm is followed three days later by the storm of February 14-18, 1938, with its center transposed 90 miles to the north and the rainfall pattern rotated by 20 degrees to maximize its coverage over all the tributary basins on the lower Mississippi River.

To convert Hypo-Flood 58A into the project design flood, the Mississippi River Commission developed the flood flows that would occur from the three storms and routed them through the tributary systems under three conditions: unregulated by reservoirs; regulated by reservoirs that existed in 1950; and regulated by existing reservoirs, plus those proposed to be constructed in the near future (1960 timeframe). The flood flows were then routed down the Mississippi River to determine the peak discharges at key locations. The Mississippi River Commission selected the 58A flood with near-future reservoirs condition, referred to as 58A-EN (existing or near completion), as the basis for the project flood flow line and adopted it as the project design flood.

The peak discharges for the revised project design flood were 2,360,000 cfs at Cairo; 2,890,000 cfs at Arkansas City; and 3,030,000 cfs at the latitude of Red River Landing.

It is important to note the 58A-EN is the project design flood for the main stem features between Cairo and the Head of Passes. MR&T levees between Cape Girardeau and Cairo and along the Arkansas River and Red River are designed with flow lines resulting from adopted tributary design flows.

Following the 1973 flood, the Mississippi River Commission once again reviewed the adequacy of the project design flood. The review concluded that the thorough approach used in 1955 was based on sound technology that was still reliable by current standards. The project design flood peak discharges remained unchanged.

Following the 2011 flood, the commission initiated an updated flowline study as recommended in the 2011 post-flood report. The study is scheduled for completion in 2016.

Conveying the Project Design Flood

Levees are the mainstay of the MR&T project flood control plan. The levee system protects the vast expanse of the developed alluvial valley from periodic overflows of the Mississippi River. The main stem levee system begins at the head of the alluvial valley at Cape Girardeau, Mo., and continues to Venice, La., approximately 10 miles above the Head of Passes near the Gulf of Mexico. The MR&T levee system includes 3,787 miles of authorized embankments and floodwalls. Of this number, nearly 2,216 miles are along the main stem Mississippi River and the remaining levees are backwater, tributary and floodway levees.

The MR&T levee system design incorporates technological breakthroughs from the science of soil mechanics that take into account the type, condition and moisture content of material used in the construction of the levees. The integrity of the current levee system is enhanced by advancements in the design, construction, installation and maintenance of seepage control measures, to include landside berms, drainage trenches, drainage blankets and relief wells. More than 1,000 miles of articulated concrete mattress revetment also protect the levee system from scour by the river.

In an effort to further guarantee the soundness of the levee system, levee districts and other local sponsors implement strict annual levee maintenance programs with their own labor and funds. Activities include mowing, clearing brush and trees, filling holes,

The MR&T levee system - the backbone of the flood-control program.

MR&T levee between Baton Rouge and New Orleans, La., during 2011 flood.

restoring rain washed areas, clearing drainage ditches, correcting drainage problems and spraying chemicals to control noxious and unwanted growth. Personnel from the Corps of Engineers ensure that maintenance requirements are met through annual inspections. These inspections are also used to identify any deficiencies and weak spots in the levee system so that immediate corrective actions can be taken. The addition of 15-foot wide, all-weather access roadways on top of the levee system aids federal personnel and local levee districts during the inspection process and during flood-fighting operations.

To maximize protection from floods, current levee grades provide for freeboard – the distance between the project design flood flow line and the top of the levee. The presently authorized freeboard is a minimum of three feet above the project design flood on the Mississippi River levees below Cairo, Ill., and two feet on the Atchafalaya basin floodway levees. Levee grades between Cape Girardeau and Cairo and along the south banks of the Arkansas and Red rivers provide for a three-foot minimum freeboard over the maximum tributary flood meeting the maximum flood of record on the Mississippi River, with provisions to ensure that the same flood meeting the project design flood will not overtop the levee. In the vicinity of New Orleans, La., project levees are authorized up to 5.7 feet of freeboard because of the increased danger to the urban areas from wave wash and storm surges that are common along coastal areas.

When flood stages begin to approach project design flood dimensions, additional project features operate to control and convey potentially damaging floodwaters to relieve stress on the levee system. A synopsis of how

the MR&T project conveys the project design flood follows:

The Confluence Area

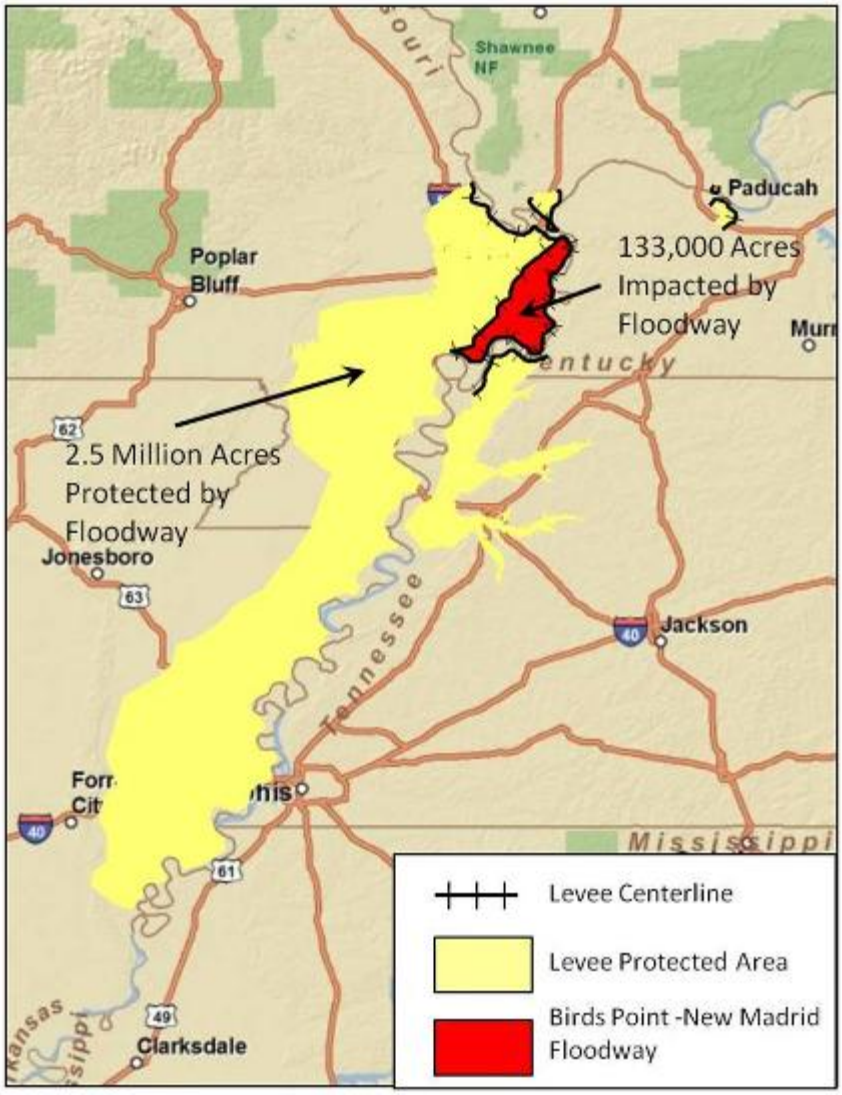
The first key location on the flood control system is in the vicinity of Cairo at the confluence of the Mississippi and Ohio rivers. When the flood stage reaches a critical level on the Cairo gage, the Birds Point-New Madrid floodway is placed into operation to make room for the river and reduce pressure on the levees and floodwalls on the east bank at and above Cairo, the east bank levees opposite the floodway and the west bank levee extending from Commerce to Birds Point.

The floodway, completed in 1933, varies in width from about three to ten miles. The levee is defined by a 56-mile long frontline levee on the east and a 36-mile long setback levee on the west. A 1,500-foot gap at the lower end of the floodway separates the frontline levee from the setback levee. The floodway is designed to divert up to 550,000 cfs from the Mississippi River under project design flood conditions and to provide up to five feet of stage lowering in the vicinity of Cairo, with smaller reductions above Cairo and through the floodway reach.

The floodway has two fuseplug levees: one at its upper and one at its lower end. The fuseplug sections are levees constructed to a lower height than the main stem levees. The floodway is activated when sections of the frontline levee naturally overtop or are artificially crevassed. The floodway requires timely operation to ensure its design effect during a flood approaching the project flood magnitude. For this reason, the plan of operation involves the placing and detonation of explosive slurry that is pumped into pre-placed pipes imbedded in the levee at the required crevasse locations.

The operation of any floodway within the MR&T project is directed by the president of the Mississippi River Commission after consultation with the Chief of Engineers. Flood conditions prompted operation of the Birds Point-New Madrid floodway in 1937 and 2011.

The Mississippi River Commission credits the floodway for reducing the crest at Cairo by 3.5 feet in 1937 and approximately four feet in 2011.



There are two major reservoirs - Kentucky and Barkley lakes - on the Tennessee and Cumberland rivers that are not features of the MR&T project, but are authorized through the 1944 Flood Control Act to reduce flood stages on the Mississippi River in the vicinity of and downriver from Cairo. Because of the close proximity of the reservoirs to the Birds Point-New Madrid floodway, their regulation has a major predictable impact on the operation of the floodway. The impacts of these reservoirs, along with dozens of additional tributary basin reservoirs, were accounted for in the development of the MR&T project design flood.

The Mid Section

Between the lower end of the Birds Point - New Madrid floodway and the Old River Control Complex, the project design flood is confined by levees on the west bank and levees and a high bluff on the east bank. The confinement of the project design flood in this stretch of the river was made possible by a comprehensive corrective dredging program conducted between 1932 and 1942.

The program consisted primarily of manmade and artificial cutoffs at 16 river bends. The cutoffs and other channel rectification measures greatly improved the flood-carrying capacity of the channel. The program initially lowered flood stages by 12 feet at Arkansas City and six feet at Vicksburg, although the river has since readjusted and negated some of those benefits.

The levee system in this segment of the project is supplemented by four backwater areas, located at the mouths of the St. Francis, White, Yazoo and Red rivers, that provide more than 1.6 million acres of natural flood storage under project design flood conditions:

- St. Francis backwater area - 500,000 acres
- White River backwater area - 145,000 acres
- Yazoo backwater area - 634,000 acres
- Red River backwater area - 373,000 acres

The backwater areas are designed to provide room for the river to expand when the backwater levees, which are constructed to lower heights than main stem levees, are overtopped at a time sufficient to reduce project flood peak stages. The backwater areas represent the last line of defense against the project design flood. When flood stages on the Mississippi River or its tributaries subside, floodwaters from within the backwater areas are evacuated through floodgates and/or pumping stations.

Cutoffs executed at the infamous Greenville Bends in the 1930s.

The Engineered Section

The MR&T project in Louisiana amounts to an elaborate plumbing system, with multiple entrance, transfer and exit points needed to accommodate the 3,000,000 cfs expected under the project design flood. In that regard, the Mississippi River between Old River and New Orleans is one of the most engineered sections of river. The goal of the system in this reach of the river is to divert flows a little at a time so that the Mississippi River discharge will not exceed the manageable rates of 1,250,000 cfs past New Orleans and 1,500,000 cfs past Baton Rouge, while ensuring a distribution of 30 percent of the combined waters and sediment of the Mississippi and Red rivers at the latitude of Red River Landing pass through to the Atchafalaya basin.

Bonnet Carré Spillway during 2011 flood.

The Old River Control Complex was constructed to prevent the Atchafalaya from capturing the Mississippi River. Three separate structures comprise the Old River Control Complex. The low sill structure and the auxiliary structure remain operable at all river stages, but the overbank structure is only operated during larger floods. During project flood conditions, the Old River Control Complex is designed to divert up to 620,000 cfs from the Mississippi River to the Atchafalaya River.

Opening of Morganza Floodway during 2011 flood.

The next key location in the system is the Bonnet Carré spillway, located approximately 30 miles above New Orleans. The 7,200-foot long spillway structure is governed by 350 intake bays and connects to a 5.7 -mile long floodway that empties into Lake Pontchartrain.

The floodway is designed to divert up to 250,000 cfs from the Mississippi River, thereby ensuring a peak discharge flow under project flood conditions at New Orleans not to exceed 1,250,00 cfs. Because the Bonnet Carré spillway has a lower threshold than the Morganza floodway in terms of Mississippi River discharge, it activates earlier in a flood event than most flood-control-only features in Louisiana. Since its completion in 1932, the Bonnet Carré floodway has operated ten times - 1937, 1945, 1950, 1973, 1975, 1979, 1983, 1997, 2008 and 2011.

Approximately 30 miles downstream from Old River, the MR&T flood control plan provides for a major diversion of floodwaters from the Mississippi River to the Atchafalaya basin through the Morganza floodway. Governed by a 3,900-foot long and a 125-bay intake structure, the floodway is designed to divert up to 600,000 cfs from the Mississippi River during the project design flood. The Morganza floodway is operated when the Mississippi River flows below Morganza are projected to exceed 1,500,000 cfs, thereby assuring that flows between Morganza and the Bonnet Carré spillway remain at or below 1,500,000 cfs. For this reason, the Morganza floodway would typically operate after activation of the Bonnet Carré spillway. The Morganza floodway, completed in 1953, has only operated during the 1973 and 2011 floods.

The West Atchafalaya floodway extends along the west side of the Atchafalaya River. The floodway contains an eight-mile long fuseplug section of levee at the head of the floodway. The floodway is designed to divert 250,000 cfs and is placed into operation when the fuseplug section is crevassed or when the west bank Atchafalaya River levee is overtopped. The West Atchafalaya floodway would be the last of the floodways to be used under the project design flood. It has not been operated to date.

The Atchafalaya River, the Morganza floodway and the West Atchafalaya floodway converge at the lower end of the Atchafalaya River levees to form the Atchafalaya basin floodway. This floodway is designed to carry 1,500,000 cfs or nearly one-half of the project flood discharge of 3,000,000 cfs at the latitude of Old River. The floodway is confined on either side by levees to a point below the latitude of Morgan City, La., whereby 1,060,000 cfs is conveyed to the Gulf of Mexico by the Atchafalaya River and the remaining 440,000 cfs is passed to the Gulf through the Wax Lake outlet.

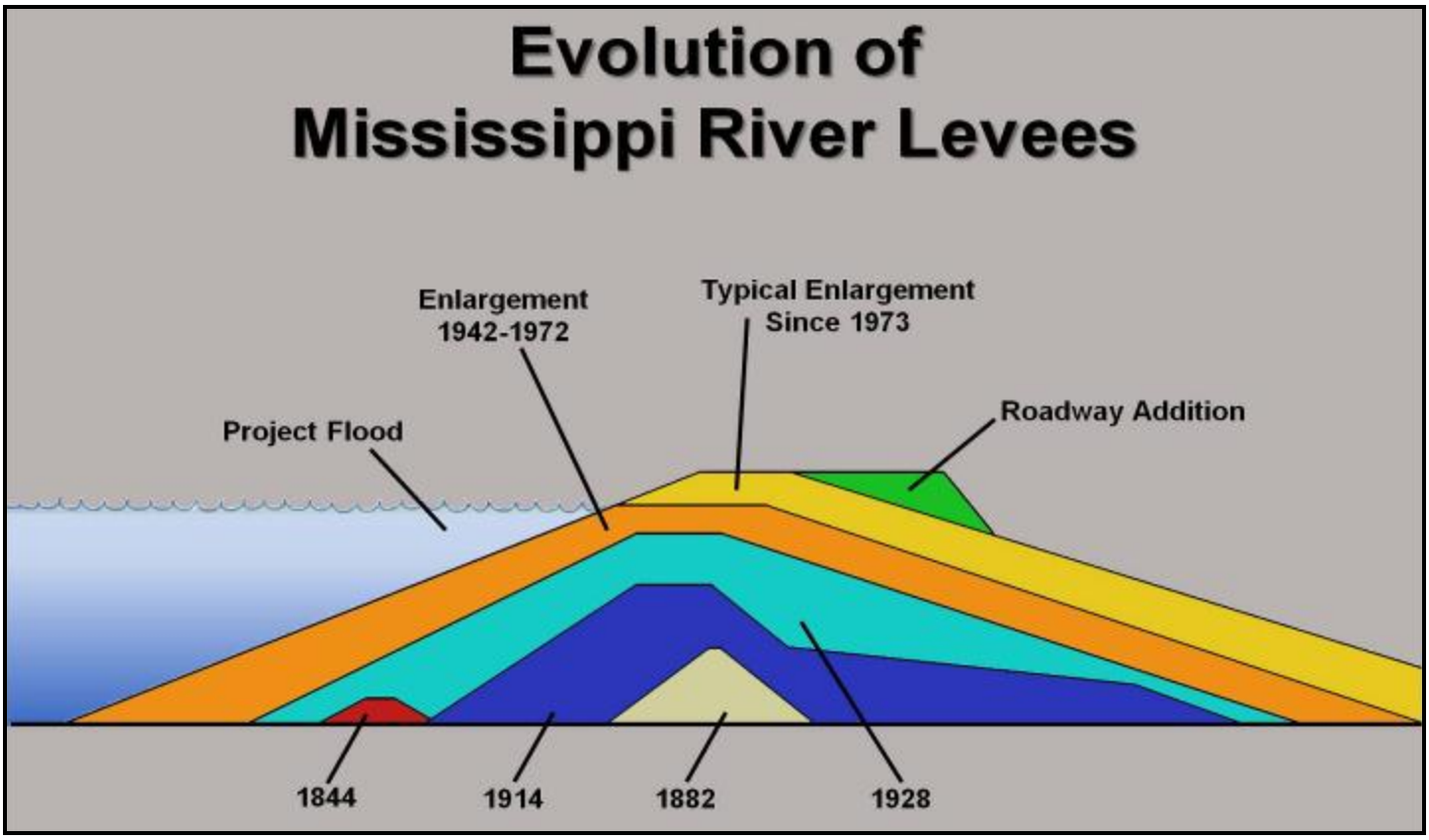
History of the MR&T Project

Prior to the tragic 1927 flood, the federal government, states and levee districts attempted to control floods on the lower Mississippi River by building levees high enough to withstand the last great flood of record. The devastation wrought by the 1927 flood demonstrated that the pre-flood levees-only policy could not properly protect the alluvial valley from the ravages of the Mississippi River. The confined channel along the river simply did not have the capacity to pass great floods without a considerable, and perhaps unsafe, increase in the height of the levee system. To this end, the nation galvanized its support for a comprehensive and unified system of public works within the lower Mississippi Valley that would provide enhanced protection from the greatest probable flood with a reasonable chance of occurring, while also providing an efficient navigation channel.

Major General Edgar Jadwin

The 1928 Flood Control Act authorized a 10-year, $300 million plan championed by Maj. Gen. Edgar Jadwin, the Chief of Engineers. Known initially as the Jadwin plan, the new project sought to repair and strengthen the battered levee system and establish five floodways. The floodways were intended to safely divert excess flows from a hypothetical flood – approximately 25 percent greater than the 1927 flood – in order to relieve pressure on the levees. The five floodways provided in the original legislation were the Birds Point-New Madrid floodway in southeast Missouri; the Boeuf floodway through the Boeuf basin in southeast Arkansas and northeast Louisiana; the East and West Atchafalaya floodways paralleling the Atchafalaya River; and the Bonnet Carré floodway located 30 miles upriver from New Orleans.

The inclusion of floodways in the MR&T flood control plan certainly represented a marked and necessary turnaround in the engineering policy practiced prior to the 1927 flood. The 1927 flood had forced that change, but even in the wake of that devastating flood a controversy emerged over the reality of actually implementing the floodways. Many residents in the alluvial valley were ill prepared for that reality - one that assured private land once protected by levees would now be subject to inundation to benefit private landowners elsewhere in the valley. Opposition to the floodways, particularly over the lack of compensation for the landowners in the Boeuf and Atchafalaya floodways, precipitated a crisis early in the evolution of the MR&T project that almost led to a return to the pre-1927 flood control policy.



A lawsuit filed in 1929 over the Boeuf floodway resulted in an injunction that restrained the federal government from proceeding with any work on the floodway guide levees until the Corps of Engineers acquired necessary land rights and paid proper compensation to landowners. The injunction prompted the Corps of Engineers to suspend work on the Atchafalaya floodways as well.

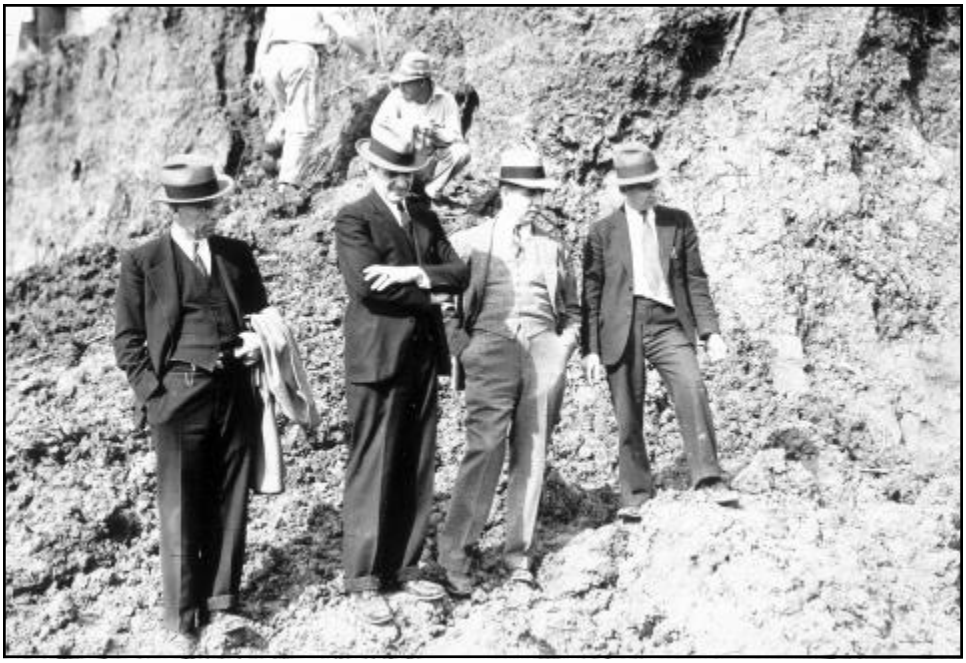
The United States Supreme Court seemingly settled the dispute in February 1932 and dismissed the lower court's injunction, but in reality the issue was not fully resolved. The Supreme Court ruled that the enactment of the 1928 act involved the intentional taking of the complainant's land. While the Fifth Amendment did not entitle the complainant to be paid in advance, landowners could file for compensation under existing laws. To this end, the federal government adopted the stance that if the guide levees within the Boeuf and Atchafalaya floodways were not constructed, then the federal government held no liability toward compensation for flowage rights.

By the close of 1932, the MR&T project was in a precarious position from the viewpoint of a systematic flood control system capable of passing the project design flood called for in the 1928 act. At the Birds Point–New Madrid floodway, work on the setback levee commenced in October 1929 and was nearly complete, as was all work in connection with the construction of the drainage ditches and appurtenant structures necessary to carry the drainage intercepted by the setback levee. Some work remained, but for all intents and purposes the floodway was operational. Near the extreme southern end of the MR&T project, the Bonnet Carré floodway was also operational. Work on the 350-bay spillway also began in October 1929, and all concrete work was finished by early February 1931. In between those two features flowed nearly 900 miles of Mississippi River with levees as the sole means of protection

from the project design flood, as reservoirs and other flood control techniques had yet to be authorized. The levees at the entrance to the Boeuf and Atchafalaya floodways remained at their pre-1927 flood grade and section. These low levees, known as fuseplug levees, were designed to overtop and crevasse during larger floods, allowing excess flows into the floodways. That water, in turn, would be funneled by the guide levees to the sea or to a backwater area for storage. The absence of guide levees within the proposed floodways, however, left no way to contain any diversion if the fuseplug levees functioned as designed.

In January 1932, the Mississippi River Commission requested and received congressional approval to launch an experimental program designed to increase the flood-carrying capacity of the channel to allow the Mississippi River to carry more water at lower stages between the mouth of the Arkansas River and Old River. The program was based largely on cutting off numerous river bends and using corrective dredging techniques to realign the channel and increase its velocity to scour the river bed deeper and increase the cross section of the channel. Within three years, the commission facilitated eight cutoffs. While none of the cutoffs and related corrective dredging measures had fully developed, actual observations on the river corroborated the findings of model tests conducted at the Waterways Experiments Station: the experiential program was succeeding in increasing the flood-carrying capacity of the channel.

Such improvements emboldened the Mississippi River Commission to recommend several sweeping modifications to the MR&T project in a 1935 report. Several of the proposed changes to the project were intended to settle the floodway issue. First the commission proposed eliminating the 1,320,000-acre Boeuf floodway and replacing it with a smaller 820,000-acre Eudora floodway farther to the south and east through the Tensas River basin. With the increased capacity of the channel to carry more floodwaters brought about by the channel realignment program, the commission believed that the Eudora floodway, though 500,000 acres smaller than the Boeuf floodway, would provide the necessary overflow relief under project flood conditions.



The Mississippi River Commission inspects a cutoff operation in the 1930s.

The Mississippi River Commission also addressed the Atchafalaya floodways. The commission proposed substituting the Morganza floodway for the East Atchafalaya floodway. Instead of being governed by a fuseplug levee in the Red River backwater area, the

Morganza floodway would be equipped with a controlled intake structure directly on the Mississippi River. A controlled intake directly on the river would provide better assurance of the integrity of the levee system from Old River to the Bonnet Carré floodway. Furthermore, the commission believed that the Morganza floodway, combined with the increased carrying capacity of the Atchafalaya River and the newly proposed Wax Lake outlet, might improve conditions in the Red River backwater area to the point that the use of the West Atchafalaya would become less likely in the future.

The Mississippi River Commission recommendations in the 1935 report extended beyond modification of the existing authorized MR&T project features by proposing outright expansion of the project to include the control of flooding on the St. Francis and Yazoo rivers, both of which were entirely located within the alluvial valley footprint. Since the 1928 act, much work had been done to improve the mainline levee system. Hundreds of miles of levees had been raised to the higher and stronger 1928 grade set forth in the original MR&T project authorization. The mainline levees afforded protection from Mississippi overflows, but the protected lands remained subject to flooding from the headwaters emanating from the higher elevated lands of the St. Francis and Yazoo basins. The commission recommended the construction of reservoirs and tributary levees in those basins in order to maximize the benefits provided by the mainline levees.

That same desire to maximize the protection afforded by the mainline levees also prompted the commission to propose a system of levees and drainage structures to protect 145,000 acres of the White River backwater area from all but larger floods approaching project flood dimensions. Protection of the White River backwater area would eventually be modified to include a pumping station (dedicated as the Graham Burke Pumping Station in 1965).

On June 15, 1936, Congress passed the Overton Act, which authorized the modifications and expansion of the MR&T project proposed by the commission. The following year, a massive flood tested the improvements achieved to date under the MR&T project. The 1937 flood produced peak discharges of 2,010,000 cfs at Cairo, 2,159,000 cfs at Arkansas City, and 1,911,000 cfs at the latitude of Red River Landing. The flood surpassed the previous high water marks on the Mississippi River between the mouths of the Ohio and Arkansas rivers, and prompted the first ever operation of the Birds Point-New

The Birds Point-New Madrid floodway after activation in 1937.

Madrid floodway on January 24. As the flood crest rolled passed Memphis, news of the unprecedented stages spurred predictions that the intended fuseplug levees along the Boeuf, Tensas and Atchafalaya basins would be overtopped and the areas, whether intended or not, would function as floodways only with no guide levees to contain the diversions. This speculation only worsened when the Bonnet Carré floodway was placed into operation for the first time on January 28.

The predictions for devastation in the delta regions of Arkansas, Mississippi and northeast Louisiana, though, never became reality. The cutoff and corrective dredging efforts had dramatically increased the flood-carrying capacity of the channel between the Arkansas River and Old River. For rising stages above 45 feet on the Arkansas City gage, the discharge of the 1937 flood approached 700,000 cfs in excess of that the 1929 flood - an increase of 50 percent - but was carried at the same stage. The 1937 flood may have surpassed the previous high water marks above the mouth of the Arkansas River, but the flood fell short of the project design flood between the Arkansas River and Old River.

By the onset of 1941, the commission had facilitated a total of 11 cutoffs through its continuation of the channel rectification program. With the increase of the flood-carrying capacity of the river as demonstrated by the 1937 flood, and the 1936 Flood Control Act's authorization of dozens of non-MR&T project reservoirs that promised greater regulation of flows along the major tributaries, particularly on the Arkansas and White rivers, the commission again proposed modifications to the project. These proposals ultimately led to the outright abandonment of the Boeuf and Eudora floodways in favor of higher mainline levees. Confining the Mississippi between the levees necessarily equated to greater backwater flooding in the Yazoo and Red River backwater areas. To this end, the commission recommended a system of backwater levees, drainage structures and pumping plants to provide protection for 634,000 acres in the Yazoo backwater area and 393,000 acres in the Red River backwater area from ordinary floods, while maintaining their natural reservoir effects during floods approaching project flood dimensions.

The 1941 Flood Control Act authorized the MR&T project modifications. Thus, by 1941 the MR&T project, through the dramatic impacts of the channel rectification program and the authorized modifications stemming from the 1936 Overton Act and the 1936 and 1941 flood control acts, had been transformed from a 10-year, $300 million project into a truly comprehensive navigation and flood control program based on significantly increased expenditures, higher levees, fewer and smaller floodways, reservoirs, tributary improvements, backwater protection and more extensive channel improvements.

The transformation of the MR&T project, however, was just beginning. The Mississippi River Commission concluded as much in its annual report of that year, stating "It would be rash to say that the plans now approved, or even as they may be modified in the near future, are a complete and final answer to the flood and navigation problems in the valley." Within a year of the 1941 act, the commission executed three additional artificial cutoffs, bringing the total number of manmade cutoffs carried out under the channel rectification program to 14. These cutoffs, when added to two natural cutoffs at Yucatan and Leland bends, and the channel rectification program shortened the low-water channel of the Mississippi River by 170 miles, which reduced travel times and transportation costs. More importantly, the cutoffs, corrective dredging and other channel improvements significantly lowered the flood line between Memphis and

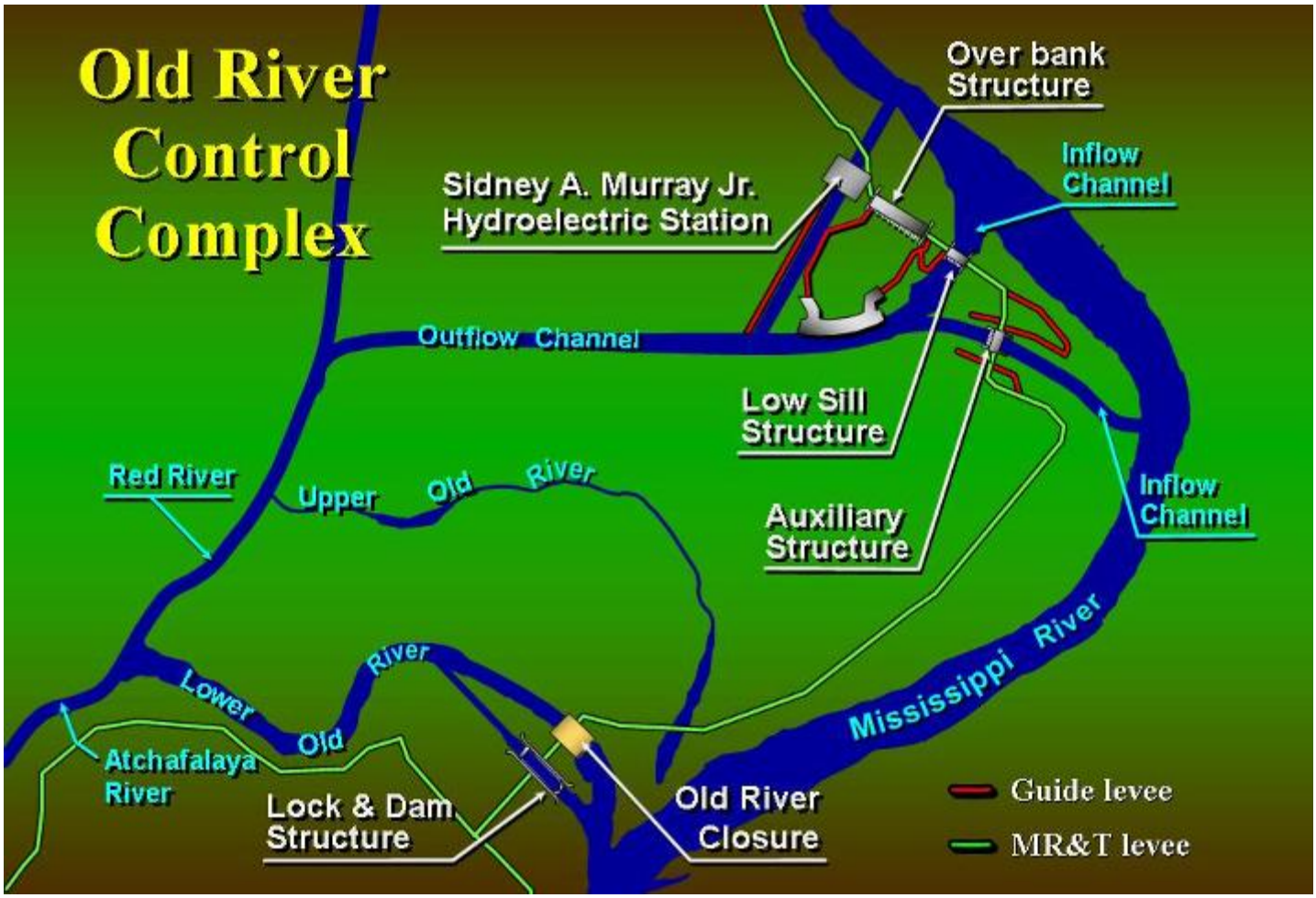
Old River, with reductions up to 12 feet at Arkansas City. In 1944, the commission reported that the river had achieved "the best alignment, the best navigation channel, and the greatest flood-carrying capacity it has ever had." To maintain and protect those desired results, the commission embarked on a massive $200 million channel stabilization program for navigation and flood control that consisted of a large-scale bank revetment program, channel contraction works and dredging.

As the Mississippi River Commission set about the task of maintaining the improved channel alignment and the achieved stage lowering, it also continued to push other project features to completion. By 1945, the Morganza floodway was the only one of the four floodways not fully constructed, although it was considered operational for emergency purposes despite the fact that the gated spillway would not be completed until 1954. Progress was being made on the project reservoirs as well. Wappapello dam on the St. Francis River was completed in 1941. Sardis and Arkabutla dams in the Yazoo basin were completed in 1940 and 1942, respectively. The remaining authorized Yazoo basin dams – Enid and Grenada – were underway, though they would not be completed until 1952 and 1954, respectively.

With World War II spending restrictions removed, Congress authorized the first post-war modifications to the MR&T project through the 1946 Flood Control Act. The 1946 act essentially expanded the project into nearby tributary basins by providing flood control on the Boeuf and Tensas rivers and Bayou Macon; flood control on the Big Sunflower, Little Sunflower, Hushpuckena and Quiver rivers; expansion of the Yazoo Headwaters Project; the Bayou des Glaises diversion channel; levees along the north bank of the Arkansas River; flood protection on the White River; the Tiptonville and Obion levees; and the improvement of St. John's Bayou. Two years later, the 1948 Flood Control Act authorized channel improvements for flood control and drainage in the West Tennessee tributaries and L'Anguille River in the St. Francis basin. The 1950 Flood Control Act expanded protection in the Red River backwater area and, for the first time, authorized extensive levee and drainage improvements in the St. Francis backwater area, to include a pumping plant later dedicated as the W.G. Huxtable Pumping Plant in 1977.

The act also authorized flood control, water supply and drainage improvements for the Grand Prairie-Bayou Meto area in Arkansas; and flood control improvements in Orleans

W.G. Huxtable pumping station.



Parish; flood protection project for Des Arc, Ark.; flood protection on the Ouachita River at Jonesville, and the incorporation of the Lake Pontchartrain levee into the MR&T project.

The renewed emphasis on channel stabilization brought about by the channel rectification program prompted several studies seeking to establish a better understanding of the major factors leading to the development of the river's course and behavior. One prominent study, conducted by Harold Fisk, examined the sequence of events in the evolution of the lower Mississippi Valley. In the aftermath of that study, Fisk informed the Mississippi River Commission that the Atchafalaya River's continuing increase of flow indicated a definite possibility that the flow of the Mississippi River would be captured by the Atchafalaya River. In 1950, the Corps of Engineers commissioned Fisk to examine the issue more thoroughly. In 1952, Fisk again reported that the Atchafalaya River would continue to enlarge until it captured the Mississippi.

In 1953, the Mississippi River Commission recommended a plan to dam Old River and to build structures to control the amount of water flowing from the Mississippi River into the Atchafalaya River. Design engineers proposed two control structures – a low sill structure to operate at all times and stages, and an overbank structure to operate only during floods. The plan also envisioned a navigation lock to maintain the navigational connection among the Mississippi, Atchafalaya and Red rivers. The Old River control structures were to be operated so as to maintain the 70-30 percent distribution

of flow and sediments between the lower Mississippi River and the Atchafalaya River in approximately the same proportions as occurred naturally in 1950. Congress authorized the Old River control structures through the 1954 Flood Control Act.

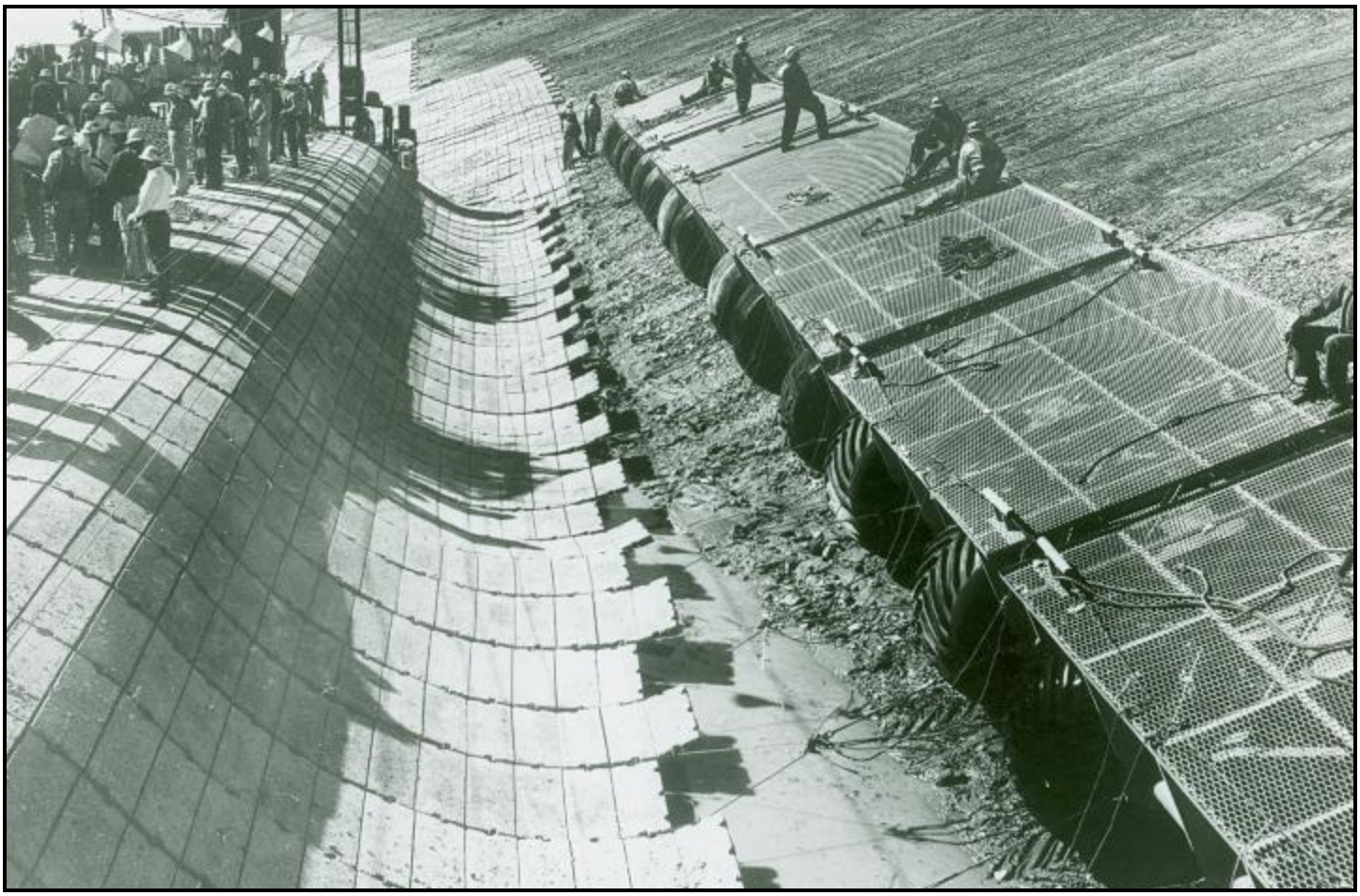
Construction began almost immediately in 1955 and the entire complex was completed and operational by 1962 at a total project cost of $67 million.

Caernarvon Freshwater Diversion structure.

The revelation of the dilemma at Old River foreshadowed changes for the MR&T project. Recognizing that more than 25 years had passed since the original authorization of the project in 1928, the Senate Committee on Public Works requested a thorough examination of all components of the MR&T project in 1954. As part of this review, the Mississippi River Commission and the Weather Bureau conducted a cooperative study aimed at reviewing the adequacy of the project design flood.

The resultant study led to the adoption in 1956 of a new or revised project design flood that took into account previously unavailable data regarding the sequence, severity and distribution of past major storms, as well as the storage capacity of dozens of existing and near -future tributary reservoirs. The peak discharges for the revised project design flood were 2,360,000 cfs at Cairo; 2,890,000 cfs at Arkansas City, and 3,030,000 cfs at the latitude of Red River Landing.

The commission included the findings of the project design flood studies as part of an exhaustive six-volume study that made several recommended changes to the MR&T project. Published as House Document No. 308, 88th Congress, 2nd Session, the report recommended extensive channel improvements and bank protection below Baton Rouge; improvement of the main stem levee system; modification of the Birds Point-New Madrid floodway, to include raising the frontline and setback levees and revising the operating plan; improvement of tributary levees on the Arkansas, Red and White rivers; channel improvements for the Boeuf and Tensas rivers, the Bayou Macon tributary basin, the Yazoo headwater area and Obion Creek; four salinity-control or freshwater diversion structures (only two have been built, to date: Caernarvon in 1991 and Davis Pond in 2002) in the lower Mississippi River Delta Region, and additional improvements to the Red River backwater area, to include drainage structures and a 4,000 cfs pumping plant (Tensas-Cocodrie pumping plant completed in 1987). The report also recommended altering the Yazoo backwater plan authorized in the 1941 act by replacing the three pumping stations with improved gravity drainage structures at



Revetment operations.

Steele Bayou (completed in 1969) and Little Sunflower (completed in 1975) and a 20-mile long and 200-foot wide channel to connect the Sunflower River and Steel Bayou ponding areas to the new drainage structures. The 1965 Flood Control Act modified the project in general accordance with the recommendations contained within House Document No. 308 and increased the monetary authorization of the MR&T project by $182,481,000, bringing the total project monetary authorization to $1.7 billion and the total estimated first cost of improvements to $2.4 billion.

Armed with clear authorizations and generous appropriations dating back to the 1944 act, the Corps of Engineers and the Mississippi River Commission pushed forward with construction of the MR&T project. Following the 1950 flood, which produced peak discharges of 1,624,000 cfs at Cairo, 1,791,000 cfs at Arkansas City, and 2,054,000 cfs at the latitude of Red River Landing, the lower Mississippi Valley underwent a 22-year period without experiencing major flooding. With no major floods to hinder construction, significant progress was made toward completing various authorized features of the project, such as the channel improvement and stabilization program for instance. By the end of 1950, slightly more than 193 miles of bank revetment had been put into place and survived the onslaught of the river. The Corps of Engineers had also constructed the roughly 38 miles of dikes authorized in the 1928 act, but had not yet begun construction of the contraction works

authorized in the 1944 act. In the 1950s, however, the Mississippi River Commission developed a long-range master plan for stabilizing the river between Cairo and Baton Rouge. By the close of 1972, approximately 675 miles of effective bank revetment and 119 miles of dikes contained in 83 different dike systems had been placed by the Corps of Engineers.

In response to environmental laws passed in the late 1960s and early 1970s, the commission launched the Lower Mississippi River Environmental Program, a comprehensive program of environmental studies of the MR&T channel improvement features and nearby improvements in the floodplain. The purpose of the program was to develop environmental design considerations for channel improvement works, levee borrow pits, revetment and side channels to support healthy, abundant and diverse fish and macroinvertebrate populations. The studies collected data which engineers used to evaluate the environmental impact of project features and develop cost effective environmental design modifications, such as scoring articulated concrete mattress revetment to allow a rougher surface for plankton and macroinvertebrate organisms to attach to, which promotes an improved food chain.

The Corps of Engineers also made significant progress in the area of levee construction. By the end of the 1972 fiscal year, 1,568 miles of 1,599 authorized Mississippi River levees were in place, with 87 percent of those levees constructed to full authorized grade and section. In the Atchafalaya basin, 325 miles of the authorized 451 miles of main stem levees reached authorized grade and section, as did all of 85 miles of authorized main stem levees along the north bank of the Arkansas River and 41 miles of the authorized 60 miles of main stem levees on the lower Red River.

In 1973, flooding returned to the lower Mississippi valley with a vengeance, prompting the operation of the Bonnet Carré spillway for the fourth time and the first-ever operation of the Morganza floodway. While the flood was severe throughout the MR&T project (peak discharges of 1,519,000 cfs at Cairo, 1,879,000 cfs at Arkansas City, 2,261,000 at the latitude of Red River Landing), it hit the Atchafalaya, Red, Ouachita and Yazoo basins particularly hard. MR&T project levees performed as designed during the flood, although with the assistance of expert flood fighting and some emergency levee raises. The Yazoo and Red rivers' backwater areas, however, were hit especially hard, with more than 670,000 acres flooded in the Yazoo backwater area alone.

The most compelling drama during the 1973 flood involved the low sill structure at the Old River Control complex. The high-velocity of flow passing through the massive gates scoured a 50-foot-deep hole in front of and partially under the structure, prompting the collapse of the south guide wall and calling the entire low sill structure's integrity into question. The opening of the Morganza floodway reduced pressure on the low sill structure, but it had sustained permanent damage. After the flood, engineers lowered a camera beneath the low sill structure, which revealed that much of the foundational material around the piles supporting the structure had been washed away. The structure was designed to operate with a maximum head of 37 feet, but the structure's weakened condition lowered the maximum head to 18 feet. Engineers modified the structure to raise the head to 22 feet in order to prevent a future disaster, but the structure had been permanently weakened to such an extent that an auxiliary structure was constructed (completed in 1986), along with a non-MR&T hydropower plant constructed in 1988, to relieve pressure on the low sill structure during major flood events, and ensure the required project design flood flows can be conveyed.

The 1973 flood was the first and largest of a series of floods that occurred over the next decade. Floods once again tested portions of the

MR&T Project in 1974, 1975, 1979 and 1983, with Bonnet Carré spillway seeing activation during all but the 1974 event. The floods prompted the Corps of Engineers and Mississippi River Commission to develop solutions for two long-term flood problems within the MR&T footprint, but each ultimately faced strong legal challenges.

The Yazoo basin was particularly hard hit by major floods in the 1970s and 1980s with more than 1,000 square miles in the 1,812 square-mile Yazoo backwater area inundated during each of the events. When the 1973 flood struck the Yazoo basin, the only major backwater improvements included the Steele Bayou drainage structure and some levee construction and channel improvements.

In the aftermath of the flood, construction in the Yazoo basin quickened. In 1975, construction was completed on the 8,000 cfs drainage structure at Little Sunflower River and on the Big Sand Creek diversion channel. In 1978, construction was completed on the backwater levee from the Mississippi River levee to the west levee of the lower auxiliary channel. That same year, construction was also completed on the drainage channel stretching from the Steel Bayou drainage structure to the Big Sunflower River.

In 1979, high stages on the Mississippi River prompted the closure of the floodgates at Little Sunflower and Steele Bayou to prevent Mississippi backwater from inundating the lower Yazoo basin. With the floodgate closed, the rainfall and runoff from within the protected area became impounded behind the levee, though the flood level was lower than it would have been without the backwater levee and floodgates. To alleviate the problem, the Corps of Engineers initiated a reevaluation study of the economic feasibility of the pumping station features authorized under the 1941 Act. The recommended plan stemming from the study called for a 17,500 cfs capacity pumping station at Steele Bayou. The plan was altered in 1991 during the review by the Office of Management and Budget, prompting another round of studies. In September 2000, the Corps of Engineers released a draft feasibility report and supplemental environmental impact statement for the Yazoo backwater area. The new recommended plan included a 14,000 cfs capacity pumping station at Steele Bayou. This plan provided for the reestablishment of bottomland hardwood forest on 62,500 acres of open land as mitigation for the pumping station.

The Yazoo backwater area during the 1973 flood.

The Corps of Engineers released the final Yazoo backwater reformulation report and supplemental environmental impact statement in 2007, but the following year, the EPA vetoed the project under Section 404(c) of the Clean Water Act, leaving the lower Yazoo-Mississippi delta subject to significant backwater flooding. An alternate plan to evacuate impounded runoff has yet to be developed by the Corps of Engineers, the Mississippi River Commission or the local sponsor.

Likewise, the series of floods in the 1970s and 1980s focused attention on flood problems in southeast Missouri, where the St. Johns Bayou basin suffered from a problem similar to the Yazoo backwater area. When the setback levee for the New Madrid floodway project was completed in the early years of the MR&T project, it blocked the natural drainage of the 300,000-acre St. Johns Bayou watershed. Consequently, a series of ditches and canals were constructed to drain impounded runoff and floodgates were placed in the Mississippi River levee just above the city of New Madrid. Under normal conditions, the drainage canals and floodgates allowed St. John's Bayou to empty into the Mississippi River and keep the towns (35,000 people), infrastructure (including Interstate 55), businesses and farmland in the watershed dry. Yet, high stages on the Mississippi River in the 1970s and 1980s forced the closure of the floodgates to prevent the Mississippi from backing up into the St. Johns Bayou basin. The closed gates, in turn, trapped the headwaters of the bayou, creeks and canals and turned the watershed into a large sump.

The 1986 Water and Resources Development Act sought to remedy the situation by authorizing St. John's Bayou – New Madrid Floodway project. The act authorized the construction of a 1,000 cfs pumping station and channel improvements to evacuate water within the St. Johns Bayou basin. The act also authorized the construction of a 1,500 cfs pumping station near the 1,500-foot gap in the levee system at lower end of the New Madrid floodway. The closure of the 1,500-foot gap and the installation of floodgates had been authorized in the 1954 Flood Control Act, but some impacted landowners initially opposed the closure, favoring a pumping station instead of floodgates.

The authorized drainage improvements commenced in the 1990s and the Corps of Engineers began construction of the cofferdam and foundational work on the New Madrid floodway pumping station in 2005. The previous year, however, the Environmental Defense Fund and the National Wildlife Federation had filed a lawsuit to prevent the construction of the project. In September 2007, a U.S. District Court issued an injunction preventing further work on the project pending additional studies related to fish passage and the development of a revised environmental impact statement and ordered the Corps of Engineers to deconstruct completed work at significant costs to the taxpayers and the project sponsor. Restoration of the worksite at the proposed pumping station was completed in 2010. With the draft revised environmental impact statement undergoing development, the St. Johns Bayou watershed continues to suffer from headwater flooding and the New Madrid floodway from backwater flooding during Mississippi River floods.

By the close of 2010, the overall MR&T project stood at 89 percent complete. Since the passage of the 1928 act, the nation had contributed more than $13 billion toward the planning, construction, operation and maintenance of the MR&T project. All four project floodways were prepared to redirect a combined1.65 million cfs from the channel to relieve pressure on the levee system; the Old River Control Complex another 620,000 cfs. Four large and protected backwater areas stood ready to provide 1.65 million acres of reservoir storage or room for the river under project

flood conditions, again with the aim to relieve pressure on the levee system. Of the 2,216 miles of main stem levees authorized, all but 16 miles were in place and 90 percent were constructed to their approved grade and section. Roughly 83 percent of the 680 miles of authorized seepage control berms had been constructed and more than 1,000 miles of operative bank revetment placed to protect the integrity of the levees.

The following year, the Mississippi River tested the MR&T project like never before. In a two week period in late April 2011 and continuing into early May 2012, rainfall exceeding 600-1,000 percent of the normal average rainfall fell over a significant portion of six states in the Mississippi River-Ohio River confluence area. The rain fell just as the snowmelt crest from the upper Mississippi River and a flood crest stemming from earlier rains on the Ohio River converged at the confluence. The resultant flood established new maximum flow records from Cairo to Baton Rouge and new stage records from Cairo to Caruthersville and Vicksburg to Natchez. The unprecedented stages and high volume placed intense pressure on the levee system, necessitating activation of the Birds Point-New Madrid, Bonnet Carré and Morganza floodways. This marked the first time in the storied history of the MR&T project that three floodways were activated during the same flood event. The levees, while battered, withstood the onslaught owing largely to the activation of the floodways and the successful flood-fighting techniques employed by the levee districts without triggering the backwater areas.

If the 2011 flood tested the flood control features of the MR&T project like never before, then the extreme low-water conditions of 2012 did the same for the navigation features. Just a little more than a year after the Mississippi River established several high-water marks, low -water conditions resulting from a persistent drought that covered much of the drainage basin threatened record low levels at several gages at the height of the harvest shipping season. Yet, with nearly 320 miles of dikes to contract the low-water channel and with the Mississippi Valley Division managing dredging assets and emergency dredging contracts, the Mississippi River remained open as a safe and reliable marine instate system.

The difference between the 2011 high stages and the 2012 low stages at various locations along the river – 53 feet at Cairo, 59 feet at Memphis and Vicksburg, and 50 feet at Red River Landing – demonstrated the daunting challenge river engineers contend with while protecting developed alluvial lands from devastating floods while balancing the waterborne commercial needs of the nation.

Mississippi River & Tributaries Project

Economic Values

Congress authorized the Mississippi River & Tributaries project in 1928; one year after the devastating Great Flood of 1927 flood cut an 80-mile wide swath across the alluvial valley. The massive flood ravaged the valley by inundating 26,000 square miles of land, destroying 41,000 buildings, killing 500 people and creating up to 700,000 refugees. The flood was not merely one that impacted the valley; its consequences were felt nationwide as the raging waters put more than the 3,000 miles of rail and thousands of miles of highways out of service, severing east-west communications and commerce for months.

To prevent a similar tragedy, the nation invested heavily in a unified system of public works to provide unprecedented flood protection and a reliable commercial artery. The resultant MR&T project has four main features:

1. Levees and floodwalls to confine ordinary floods.
2. Floodways and backwater areas to provide room for the river to expand and relieve pressure on the levee system during larger floods.
3. Channel stabilization and channel improvements to provide an efficient channel that carries more water at lower stages during floods.
4. Tributary basin improvements that maximize the benefits of mainstem protection by providing reservoirs for headwater protection and interior drainage improvements.

These features work in tandem to provide a safe and dependable commercial navigation channel on the Mississippi River, while protecting adjacent towns, farms, industry, manufacturers, energy providers, public and private investment, ports and transportation systems from "uncontrolled" flooding. This increases reliability and productivity, and protects the nation's high-value investments.

The MR&T provides flood protection for:

- More than 4 million people and 900,000 households.
- 10.6 million acres of prime agricultural lands needed to feed the world.
- 3,600 miles of rail used by four major Class I freight carriers with combined (nationally) operating revenues of $50 billion in 2011.
- 5,100 miles of highways, including major sections of I-10, I-20, I-40, I-55 and I-57, needed to transport commerce.
- 12 major oil refineries with a combined capacity of nearly 3 million barrels per day.
- Hundreds of thousands of oil and gas wells and related pipelines.
- 102 power plants, including three nuclear power plants.
- Hundreds of manufacturers, which generate more than $100 billion and provide approximately 400,000 jobs.

In addition, the MR&T project provides:

- For more than 500 million tons of cargo to move annually (~$3 billion in annual transportation rate savings).
- Authorized depths for continued water commerce during severe droughts (1988, 1999, 2012).
- A commercial link from the bread basket and sugar and rice bowls of the nation to more than 30 ports, including four of the nation's busiest ports.

[1] Association of American Railroads, *Class I Railroad Statistics*, April 17, 2013. The major Class I freight operators include Burlington Northern-Sante Fe Railroad ($19.6 billion), Kansas City Southern Railroad ($1.2 billion), Canadian National Railroad ($9.1 billion), and the Union Pacific Railroad ($19.5 billion).

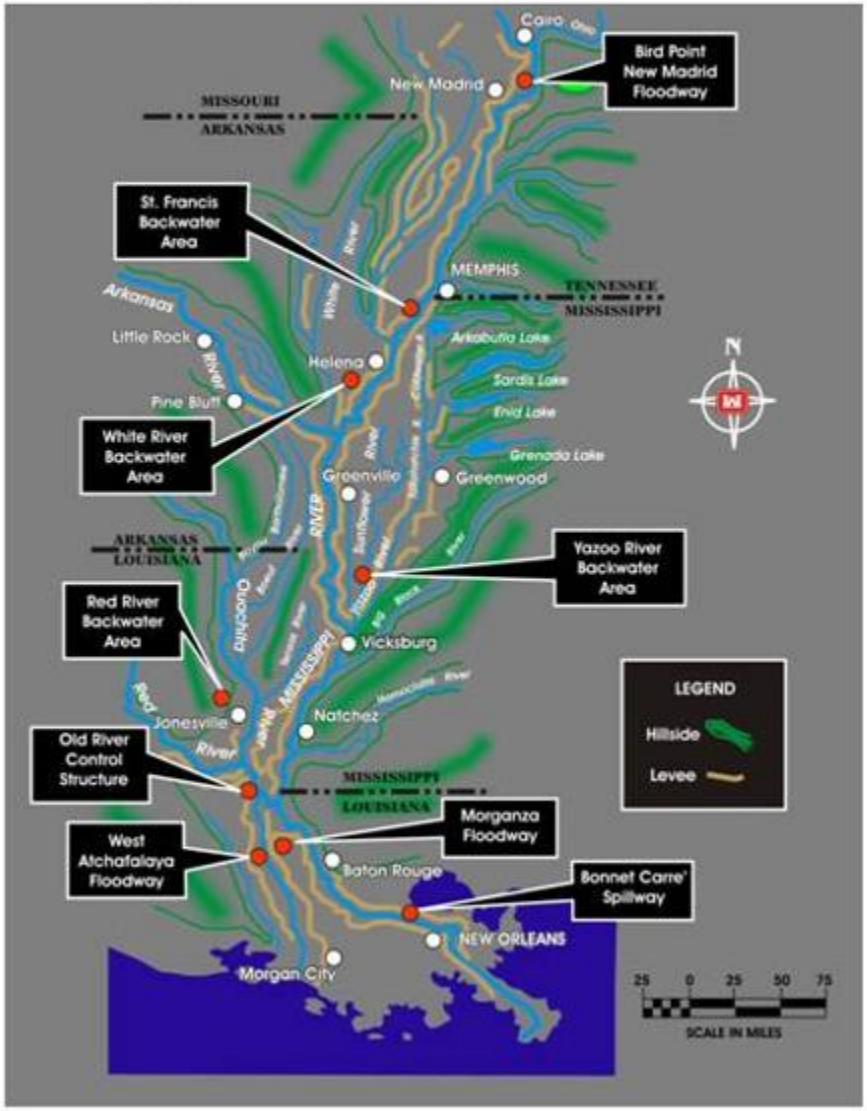
[2] Oil and Gas Journal, *List of Oil Refineries in the United States*.

[3] Industrial Economics, Inc., *Economic Profile of the Lower Mississippi Region*. This report states that in 1998 manufacturing generated $87 billion in revenues and provided 383,000 jobs. The $87 billion figure, when adjusted for inflation, amounts to approximately $126 billion in revenues in 2014.

Room for the River Concept

Flood Storage

- **Floodways = 366,000 acres**
  - Birds Point – New Madrid Floodway: 133,000 acres
  - Morganza Floodway: 71,500 acres
  - Bonnet Carré Spillway: 7,600 acres
  - West Atchafalaya Floodway: 154,000 acres
- **Backwater Areas = 1,652,000 acres**
  - St. Francis Backwater Area: 500,000 acres
  - White River Backwater Area: 145,000 acres
  - Yazoo Backwater Area: 634,000 acres
  - Red River Backwater Area: 373,000 acres



APPENDIX 1

Room for the River Concept

Diversions – Design Flow

- Birds Point – New Madrid Floodway
  550,000 cfs
- Morganza Floodway
  600,000 cfs
- Bonnet Carré Spillway
  250,000 cfs
- West Atchafalaya Floodway
  250,000 cfs
- Old River Control Complex
  630,000 cfs

MR&T capable of diverting 2.3 million cfs

APPENDIX 2

Major Mississippi River Floods in the MR&T Era

(Based on floods exceeding 1.7 million cfs at Arkansas City)

Year	Cairo	Arkansas City	Red River Landing
1927	1,626,000	1,712,000	1,461,000
1937	2,002,000	2,188,000	1,896,000
1945	1,470,000	1,911,000	2,123,000
1950	1,624,000	1,791,000	2,054,000
1973	1,519,000	1,879,000	2,261,000
1975	1,658,000	1,841,000	1,921,000
1979	1,571,000	1,811,000	2,014,000
1983	1,486,000	1,780,000	2,150,000
1997	1,195,000	1,830,000	2,112,000
2008	1,424,000	1,730,000	2,082,000
2011	2,100,000	2,293,000	1,641,000

APPENDIX 3

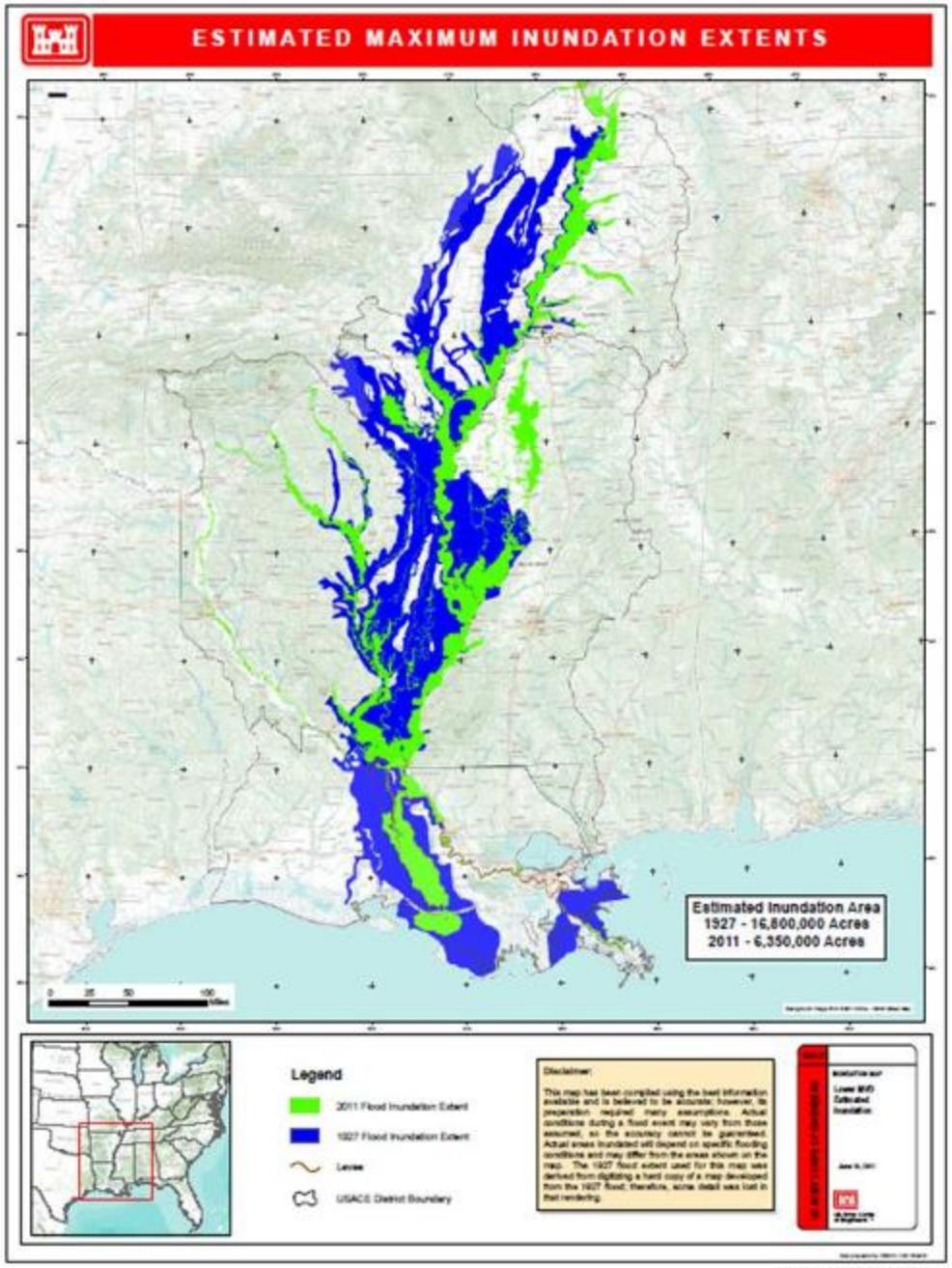
Flooded Areas

1927 Flood
vs
2011 Flood

1927 Flood = 16.8 million acres (6.73 million hectares)

2011 Flood = 6.35 million acres (2.56 million hectares)

More than 10 million acres (4.17 million hectares) not flooded in 2011



APPENDIX 4