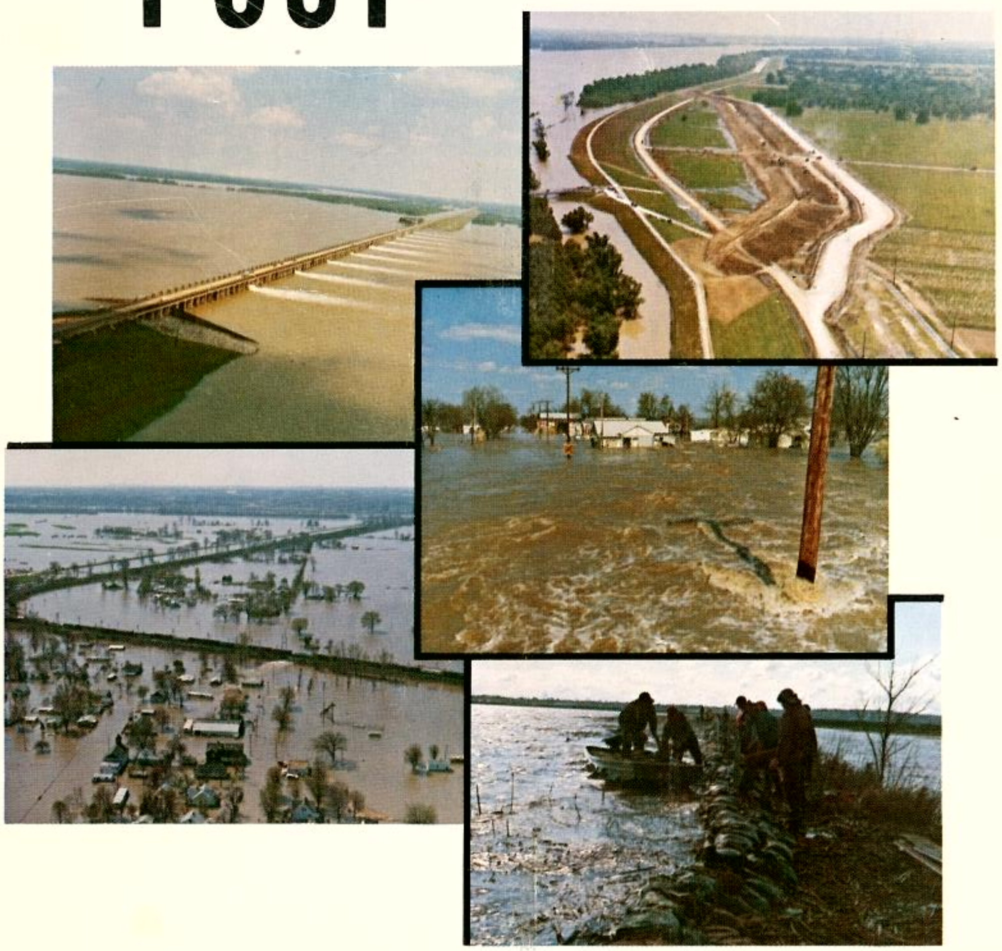
MISSISSIPPI RIVER
AND
TRIBUTARIES

POST - FLOOD REPORT

1973



DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
LOWER MISSISSIPPI VALLEY DIVISION
Vicksburg, Mississippi

MISSISSIPPI RIVER

AND

TRIBUTARIES

POST-FLOOD REPORT

1973

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SYLLABUS

Throughout the autumn of 1972, above average rainfall began to fill flood control reservoirs along the tributary streams of the Mississippi River. By December 1972, the basin had become saturated and very little additional rainfall could be absorbed. Corps hydrologists noted an ominous pattern in hydrograph readings at Cairo, Illinois, the top of the Lower Valley, where the Mississippi and Ohio Rivers join.

In early March 1973, more storms developed over the Missouri River Basin, then moved into the northeast over the Upper Mississippi and Illinois River Basins. Others blew into Arkansas, Louisiana, Mississippi, Tennessee, and Kentucky. On 9 March all indications were that a major flood had begun. Later storms in March and April added more floodwaters. It took until mid-June 1973 for the flood to run its course from the State of Iowa to the Gulf of Mexico. The magnitude of the flood varied greatly in the tributary basins, but on an overall basis and particularly on the lower Mississippi River the flood ranked as one of the great floods of Mississippi River history.

Federal flood control works throughout the basin, although many projects were still under construction, were highly effective for the purposes for which they were designed and constructed. Reservoirs and other works in the tributary basins reduced local flooding, and the reservoirs combined to lower the flood crest on the upper Mississippi River at St. Louis, Missouri, by 2 feet, and the crest at Cairo, Illinois, on the lower Mississippi River by more than 4.5 feet. Private and local non-Federal levees throughout the basin were generally designed for lesser floods and many failed despite efforts to hold them.

Although still incomplete, the complex Mississippi River and Tributaries Project for flood control on the lower Mississippi River, overall, performed splendidly. No Federal levees on the lower Mississippi were breached, and other features of the project also performed satisfactorily. As the flood developed and stage-discharge relation data were collected and studied, it became apparent that the channel capacity of both the lower Mississippi River and the lower portion of the Atchafalaya Basin Floodway had seriously deteriorated. A new Project Design Flood Flow Line was established and it demonstrated the need to raise many miles of levees to provide protection against the project flood. This superimposed a vast emergency levee-raising program in addition to the flood activities already in progress. A permanent levee-raising program based on the new flow line is an absolute necessity. This work is now under way.

Corps of Engineers emergency activities during the flood encompassed every phase of flood fighting, ranging from cooperation with small local levee or drainage districts to direct operation of major flood control structures. On the lower Mississippi River, the Birds Point-New Madrid Floodway in Missouri was readied for use, but operation did not become necessary. Bonnet Carré was again operated successfully. Old River Overbank Structure was used for the first time, as was the Morganza Floodway.

Total damages with existing projects were $1,154,770,000; damages without projects would have been $15,640,493,000; total damages prevented by projects amounted to $14,485,723,000. Without Federal projects 33,768,000 acres would have been inundated. With Federal projects 16,712,000 acres were inundated. The projects saved 17,056,000 acres from inundation. Approximately 45,300 persons were displaced and 28 deaths were attributed to the flood. Over 300 deaths were reported for the 1927 flood.

The 1973 flood again justified the Federal flood control projects in the Mississippi River Basin. However, the expanse of areas flooded, the monetary losses sustained, and the extent of human suffering experienced in 1973 clearly indicate the need for the completion of the authorized flood control works, expansion or modification of some existing projects, and the initiation of new projects in some areas.

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AUTHORITY, PURPOSE, AND SCOPE

AUTHORITY

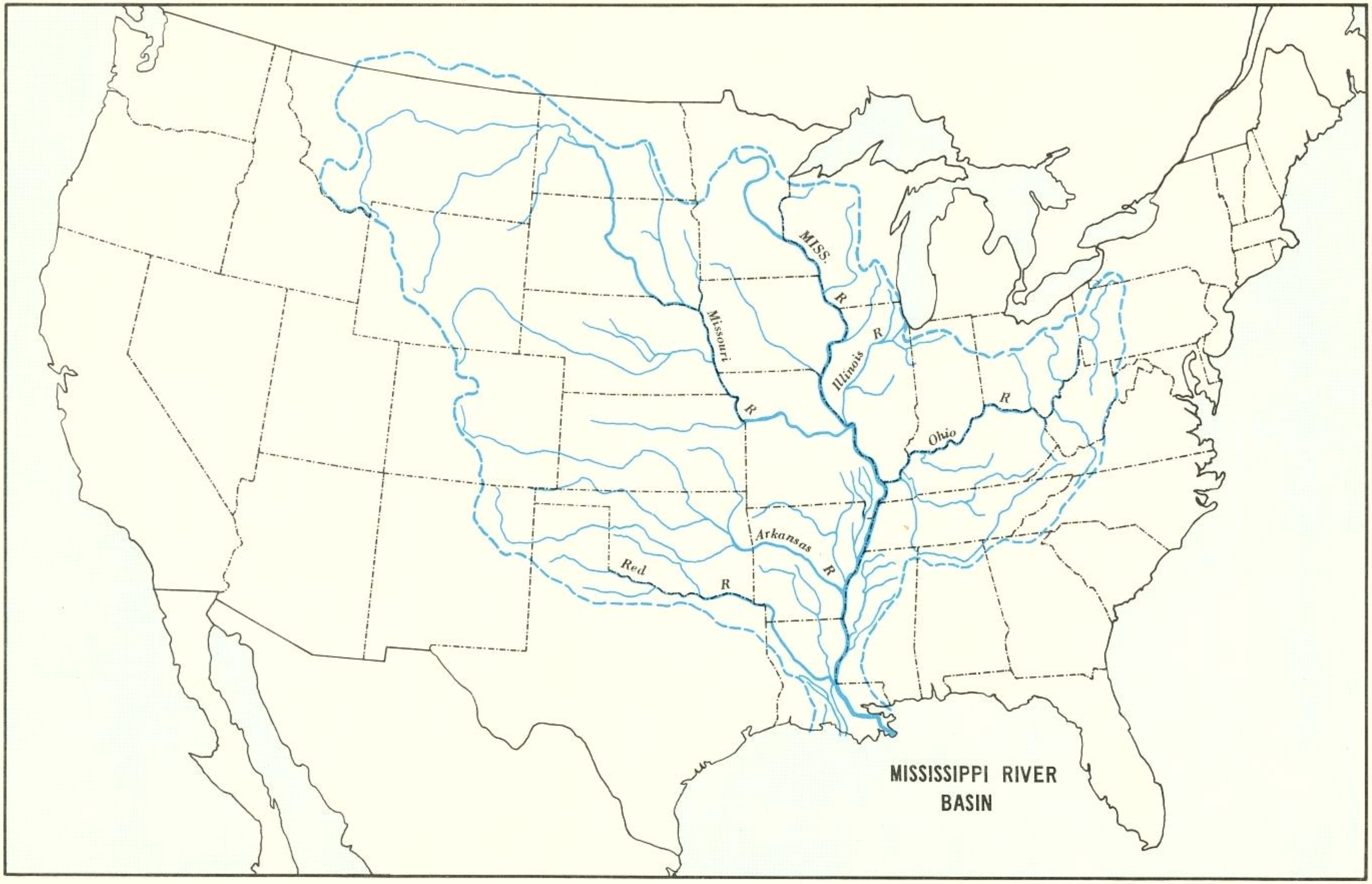
This report, covering major phases of flooding conditions experienced within the Mississippi River Basin, has been prepared in accordance with ER 500-1-1, dated 4 January 1974, and under the authorization of the Chief of Engineers contained in letter, DAEN-CWO-E, 5 June 1973, subject: Post-Flood Report, Mississippi River and Tributaries Flooding, 1973.

PURPOSE AND SCOPE

The purpose of the report is to provide a reference for information relative to the storms, subsequent flooding, and flood-fighting procedures prior to and during the 1973 flood. This report will be of particular value in evaluating flood-control needs and in planning projects responsive to these needs. It will also provide information that will be helpful in improving flood-fighting procedures.

This report presents a summary of flood information for the entire Mississippi River Basin. Separate appendixes have been prepared covering the major tributary river basins. These appendixes, which include detailed flood data, have been prepared by the Corps of Engineers District or Division having jurisdiction over the area involved as listed below. Copies of the appendixes are on file in the Office, Chief of Engineers, Washington D. C.; Office, Division Engineer, Lower Mississippi Valley Division (LMVD), Vicksburg, Mississippi; and in the originating offices for the areas under their jurisdiction.

Appendix	River Basins Included	Originating Office
A	Illinois and Upper Mississippi Rivers	North Central Division
B	Missouri River	Missouri River Division
C	Ohio River	Ohio River Division
D	Arkansas, White, and Red Rivers	Southwestern Division
E	Illinois and Upper Mississippi Rivers	St. Louis District, LMVD
F	Lower Mississippi, Main Stem; St. Francis and Lower White Rivers	Memphis District, LMVD
G	Lower Mississippi, Main Stem; Big Black and Southwest Tributaries; Ouachita, Yazoo, and Lower Arkansas Rivers	Vicksburg District, LMVD
H	Lower Mississippi, Main Stem; Atchafalaya Basin; Pontchartrain Basin; Bayou Cocodrie, Bayou Teche and Vermilion; Area Between the Atchafalaya Levees and the Mississippi River Main-Line Levees; Red River	New Orleans District, LMVD


MISS.
R
Missouri
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Illinois
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Ohio
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Arkansas
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MISSISSIPPI RIVER
BASIN

Section II

DESCRIPTION OF THE MISSISSIPPI RIVER BASIN, THE FLOOD PROTECTION WORKS, AND THE IMPACT OF THE 1973 FLOOD

BASIN DESCRIPTION

The Mississippi River and its tributaries drain a total of 1,246,000 square miles, which is 41 percent of the land area of the continental United States. About 13,000 square miles of this drainage area lie in two Canadian provinces; the remainder is within the geographic boundaries of the United States and covers all or part of 31 states. The drainage basin is bounded on the west by the Rocky Mountains, which exceed an elevation of 10,000 feet at many points. Between these mountains and the Mississippi River are the Great Plains, which vary in elevation up to 4000 feet. From the Great Plains the land slopes eastward to the Mississippi River. The Appalachian Mountain chain forms the eastern divide of the watershed. From these mountains the Appalachian Plateau extends westward at elevations varying from 2000 to 4000 feet. In contrast to the east and west divides, the northern divide is comparatively ill-defined and varies in elevation from less than 1000 feet to more than 2000 feet.

The Mississippi River rises in northern Minnesota and flows in a southerly direction for 2430 miles into the Gulf of Mexico. The Missouri River enters the Mississippi River at mile 1159 above Head of Passes, Louisiana; the Ohio at mile 964; and the White-Arkansas at mile 583. At mile 314.5, some of the flow leaves the Mississippi River through the Old River Control Structures and passes to the Gulf through the Atchafalaya River Basin. The alluvial valley of the Mississippi River extends from Cape Girardeau, Missouri, 50 miles above Cairo, to the Gulf of Mexico. This valley varies in width from 20 miles at Natchez, Mississippi, to 80 miles at Greenville, Mississippi, and has an average width of 45 miles.

The drainage areas and river miles above the Head of Passes are listed in Table 1 on the following page for some of the more important locations on the Mississippi River and the major tributaries.

BASIN FLOOD-CONTROL WORKS

TRIBUTARY BASINS

Flood-control works in the several tributary basins consist of various combinations of completed, partially completed, and authorized but not started structures and improvements. These works are comprised primarily of upstream reservoirs with flood-storage capacities, levees, floodways, and, in some cases, pumping stations for the control of impounded and seepage water within protected areas.

LOWER MISSISSIPPI RIVER

Description of the Flood-Control Plan

The Mississippi River and Tributaries Flood Control Project embodies a plan to protect the Lower Mississippi Valley against the project design flood. The plan includes the use of levees, floodways, channel improvements, and major tributary flood-control improvements. The project design flood was developed by combining severe storms of record that have occurred in the

TABLE 1

DRAINAGE AREAS OF THE MISSISSIPPI RIVER

River and Drainage Area	Area (square miles)	Applicable Gaging Station	Gaging Station Location Miles Above Head of Passes, Louisiana
Upper Mississippi, Above Alton, Illinois	171,470	Alton, Illinois	1167
Missouri, Above Hermann, Missouri	528,200	Hermann, Missouri	1256
Upper Mississippi, Above St. Louis, Missouri	701,010	St. Louis, Missouri	1144
Ohio, Above Metropolis, Illinois	203,620	Metropolis, Illinois	1001
Mississippi, Above Cairo, Illinois	921,960	Cairo, Illinois	966
Arkansas, Above Little Rock, Arkansas	158,200	Little Rock, Arkansas	741
White, Above Clarendon, Arkansas	25,500	Clarendon, Arkansas	683
Mississippi, Above Arkansas City, Arkansas	1,131,590	Arkansas City, Arkansas	547
Red, Above Alexandria, Louisiana	67,500	Alexandria, Louisiana	416
Mississippi, Above Red River Landing (latitude), Louisiana	1,245,600	Red River Landing (latitude), Louisiana	301

basin, and placing them in a pattern to produce the greatest flood that might reasonably be expected to occur. This flood will produce 3,030,000 cubic feet per second (cfs) at the latitude of Old River. Floodwaters from the upper end of the Valley would pass downstream, confined by levees or high ground except for backwater areas. Near Old River the flow would divide, with a maximum of 1,500,000 cfs continuing downstream to the Gulf through the leveed channel of the Mississippi River and the Bonnet Carré Spillway. The balance of the flood flow would be diverted through the Old River Control Structures and the Morganza Floodway to the Atchafalaya Basin, where it would be joined by water from Red River and its tributaries. This portion of the flood would pass to the Gulf through the lower Atchafalaya Basin Floodway, thence through the lower Atchafalaya River and Wax Lake Outlet.

Levees

The levee line on the west bank of the Mississippi River begins just south of Cape Girardeau, Missouri, and, except for gaps at points where there are tributary streams or high grounds, extends almost to the Gulf of Mexico (to mile 10 above the Head of Passes).

The area east of the river is protected by levees alternating with high bluffs. Between Hickman, Kentucky, and the Obion River, the area is protected by two short reaches of levee; one is 22 miles long and the other is 24 miles long. Beginning just below Memphis, Tennessee, at the head of the Yazoo Basin, there is a continuous levee to a point just above Vicksburg, Mississippi.

The east bank is largely hilly from Vicksburg to Baton Rouge, Louisiana, where the levee begins again and runs continuously to the vicinity of Point-a-La Hache, Louisiana, approximately 44.5 miles above the Head of Passes.

The White River backwater area, consisting of 149,000 acres between Helena, Arkansas, and the mouth of the White River, is protected from frequent flooding by a ring levee which connects with the main-line Mississippi River levee and which contains fuseplug sections to permit Mississippi River floodwater to enter the protected area at extremely high stages.

The Tensas-Cocodrie part of the Red River backwater area, containing 372,500 acres, is west of Natchez, Mississippi, between the Black and Mississippi Rivers, and just a few miles above the Red and Old Rivers. It is protected from floods by a loop levee with north and south extremities joining the west-bank Mississippi River levee. In order to reduce the flood crest at extremely high stages, a fuseplug section in the levee will permit floodwaters from the Red-Ouachita and Mississippi Rivers to overtop the levee.

The main-line levee terminates just above Vicksburg, Mississippi, where the Yazoo River enters the Mississippi River. The Yazoo backwater levee system has been authorized to protect the lower Yazoo Delta from backwater flooding of the Mississippi. The backwater levees are under construction, but the system is not complete and did not provide backwater protection during the 1973 flood.

Floodways

Birds Point-New Madrid Floodway—From Cairo, Illinois, to New Madrid, Missouri, the east-bank bluffs and the levee, as originally built on the west bank, left only a narrow channel through which the river could flow at flood stage. The project provides for a setback levee five miles west of the riverfront levee through this reach to reduce the flood heights to which the controlling levees above and below Cairo would otherwise be subjected and to help protect the city of Cairo. The strip of land between this setback levee and the levee adjacent to the river forms the Birds Point-New Madrid Floodway. Plans call for the floodway to be placed in operation at stages of 58 feet or higher on the Cairo gage if a stage in excess of 60 feet at Cairo is forecast. Water enters the floodway through a fuseplug section in the front levee by natural overtopping or artificial breaching. It reenters the main river through a gap in the front levee just above New Madrid. The floodway has been operated only once, in 1937, and it was helpful in reducing flood heights at Cairo and nearby areas.

Old River Control Structures—The Old River Control Structures are located on the west bank of the Mississippi River at approximately mile 314 above the Head of Passes. The structures were built to prevent the capture of the Mississippi River by the Atchafalaya River and at the same time to control flows into the Atchafalaya River and Basin. They consist of a Low-Sill Control Structure and an Overbank Control Structure, and were designed to have a combined capacity of about 700,000 cfs during the occurrence of a project flood.

The Low-Sill Control Structure is a reinforced concrete structure consisting of 11 gated bays, each having a 44-foot clear width between piers. The three center bays have a weir crest elevation of 5.0 feet below mean sea level (msl) for passing low flows, and the other bays have a weir crest elevation of 10.0 feet above msl. The highest gage reading recorded for 1973 at the structure was 61.6 feet msl, river side, on 15 May; channel side that day the reading was 59.3 feet msl. Generally, the gates of the Low-Sill Control Structure remain fully open at all times to distribute low and moderate flows except when special conditions require partial closure. The structure was fully open throughout the 1973 flood.

The Overbank Control Structure is a reinforced concrete structure consisting of 73 gated bays, each having a 44-foot clear width between piers. The weir crest elevation for all bays is 52.0 feet above msl. The gates of this structure are normally fully open to distribute flood flows between the Mississippi and Atchafalaya Rivers.

Morganza Floodway—The Morganza Floodway, located just above the town of Morganza, Louisiana, and between the Mississippi River and the Atchafalaya Basin Floodway, is designed to carry approximately 600,000 cfs of Mississippi River floodwaters to the Gulf of Mexico via the Atchafalaya Basin Floodway, thence through the lower Atchafalaya River and Wax Lake Outlet. The control structure is a reinforced concrete structure approximately 3900 feet in length supported on concrete piles, and consists of 125 gated concrete weirs, each 28.25 feet in width, with a weir crest elevation of 37.5 feet msl. The control structure is tied into the guide levee by an earth embankment. At the control structure the floodway is about 4.4 miles wide.

Bonnet Carré Spillway—The Bonnet Carré Spillway is located near the site of the old Bonnet Carré crevasse and in a straight reach of the Mississippi River approximately 25 miles above New Orleans, Louisiana. The spillway and structure were designed to convey approximately 250,000 cfs of floodwaters from the Mississippi River to Lake Pontchartrain. The structure contains 350 bays, each 20 feet wide; 176 of the bays, in four groups, have a weir crest elevation of 18.0 feet msl, and 174 of the bays, in three groups, have a weir crest elevation of 16.0 feet msl. The structure is approximately 7700 feet long.

Atchafalaya Basin Floodway—The Atchafalaya Basin Floodway extends from the confluence of the Red and Old Rivers, which form the Atchafalaya River, to the Gulf of Mexico. Guide levees constructed on the east and west sides of the basin form the floodway, which is approximately 15 miles wide. In the flood-control plan this floodway is designed to carry half of the project flood (1,500,000 cfs) to the Gulf. These floodwaters enter the floodway through the Red and Old Rivers and the Morganza Floodway. The West Atchafalaya Basin Floodway, which, in reality, is a part of the Atchafalaya Basin Floodway, lies parallel to and on the west side of the Atchafalaya River channel. Entry into this floodway is through a fuseplug levee at the north end at extremely high stages.

Channel Improvements

Improvement and stabilization of the channel of the lower Mississippi River constitute an essential part of the flood-control plan. The dredging and bank stabilization program is well along but much still remains to be done. In the early 1930's a program of channel cutoffs was inaugurated. These cutoffs would have lowered river stages by 16 feet at Arkansas City and 10 feet at Vicksburg at project design flood stages. There are 16 such cutoffs and two major chutes that developed, which originally reduced the river distance between Memphis and Baton Rouge by 170 miles.

IMPACT OF THE FLOOD

In the autumn of 1972, the residents of the Lower Mississippi Valley had not experienced a major flood for more than 20 years. A new generation of people had reached maturity without seeing the great river rampaging through the huge basin that it drains. Many of them believed that the long absence of major floods was due to the fact that the main-line levees and flood-control projects constructed by the Army Corps of Engineers had "tamed the river" and made it impossible for floods to occur.

The preliminary events that led to the flood of 1973 were subtle, and in the beginning they created more annoyance than alarm. Heavy rains plagued the basin from October 1972 through January 1973. River stages were abnormally high, and the river missed its low-water stage almost entirely. Navigation and riverfront industries began to experience difficulties from swift current, drift accumulation, wave wash, and other related problems. Farmers had trouble harvesting their 1972 crops. The ground became saturated, and runoff was rapid. Tributary streams rose, and their headwater reservoirs crept up to unusually high levels.

By the first of February, the Corps was preparing for the worst and levee boards and other local interests were being urged to consider the possibility that the spring rains could bring about a major flood crisis in 1973.

Ordinarily it is the Ohio River Basin that makes the heaviest contribution to a major flood on the lower Mississippi. Corps personnel kept a wary eye on the gage at Cairo, Illinois, but it was the upper Mississippi that provided the first flood emergencies. Intense storm systems swept over the Midwest. Major tributaries of the upper Mississippi rose rapidly, and early in March the people who lived along the river were already battling to save private levees that protected their homes, fields, and towns from overflow.

While the people along the upper Mississippi were beginning a flood fight that was soon to become a series of critical emergencies, preparations were being made on the lower reaches of the Mississippi for the flood that was forming in the tributaries. As the lower Mississippi River continued to rise in March, levees were patrolled, floodgates were closed, and flood-control structures everywhere were made ready for operation.

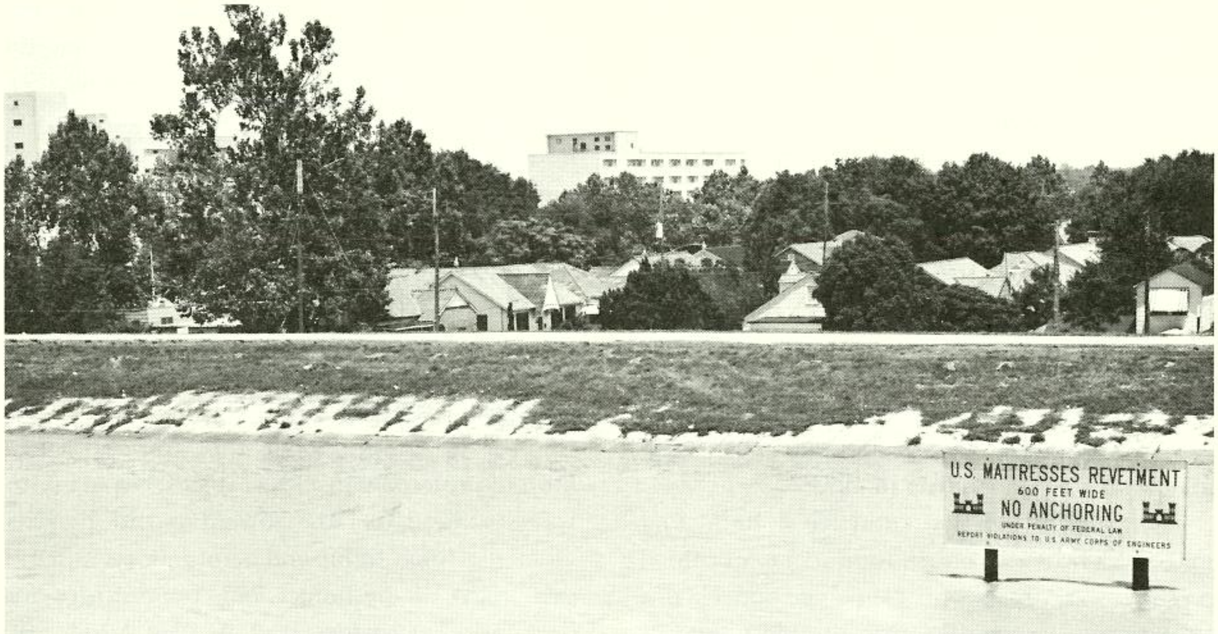
When the Cairo gage reading increased more than 21 feet during the first 15 days of March, it became obvious that a flood of major proportions was on the way. As the water rose higher and higher against the main-line levees, seepage and sand boils became a problem. As the Mississippi spilled out of its banks, backwater entered its tributaries, flooding low-lying unprotected areas and in some cases meeting a tributary headwater flood that was already causing problems in these unprotected areas. Many communities along the length of the Mississippi and on its tributaries, although many were protected from outside floodwaters, were beginning to have trouble with interior drainage. Volunteers, local interests, and State and Federal agencies were kept busy evacuating people from threatened areas, strengthening levees with sandbags, and manning pumps or making repairs. Sand boils had to be ringed with sandbags and levees had to be patrolled 24 hours a day.

On the upper Mississippi, private levees, built to protect against lesser floods, began giving way as the river rose toward record heights. Dramatic flood fights and heroic efforts failed to save many of the homes and communities and devastation was widespread. At West Alton, Missouri, and at Choteau and Kaskaskia Island the situation grew more and more critical.

At the other end of the Mississippi, a serious situation developed very suddenly at Montz, Louisiana, when a caving riverbank threatened a main-line levee. A setback levee had to be constructed, and the 44 families who lived in the village of Montz had to be relocated to new homes elsewhere. It was the first of several bank failures that had to be dealt with, but the later failures occurred in areas where fewer people were affected by construction of the setback levees.

In April, the river was well above flood stage everywhere, and in New Orleans it was rapidly approaching stages that are crucial to the safety of the city. On 8 April current and forecast conditions were such that it was necessary to opperate Bonnet Carré Spillway. About 4000 residents of the area, together with public officials and Corps personnel, gathered to see Senator Russell Long open the first gate.

In the Atchafalaya River Basin, many questions were raised about Morganza Floodway, which had never been used. Residents of the Morgan City area, at the foot of the floodway, feared that the opening of Morganza would



Slope protection pavement on east-bank Mississippi River levee in Jefferson Parish, upstream of New Orleans, Louisiana

overwhelm their city. An emergency floodwall and levee-raising project already under way in the Atchafalaya Basin, where levees are necessarily built on weak soils and tend to settle over a period of years, did little to reassure the people at Morgan City.

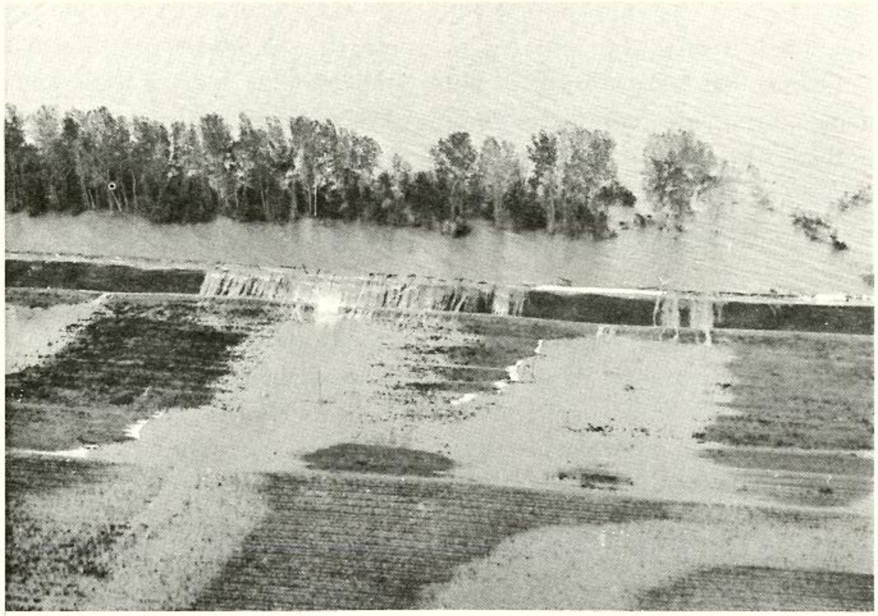
In the midst of the widespread flood fight, stage-discharge data that could only be obtained under extremely high-water conditions indicated serious channel deterioration causing many miles of controlling levees in the Lower Mississippi Basin to be inadequate to contain a project flood. This necessitated a massive emergency construction program to raise levee grades. (See Section VII for more details.)

On 12 April another crisis occurred on the lower reaches of the river when a wing wall at the Old River Low-Sill Control Structure was undermined by the river's currents and collapsed. This necessitated the almost immediate opening of both the Old River Overbank Structure and Morganza Floodway to relieve the pressure on the threatened Low-Sill Structure.

By the end of April, the upper Mississippi had produced its third crest, establishing record stages at St. Louis and other gaging stations. The flood fights at Choteau and at West Alton had been lost, as the private levees that had withstood the earlier crests were overtopped by the record stages. At Kaskaskia Island, the Federal levee which had not yet been raised to full grade and section was also overtopped and breached after an extended effort to save it.

The lower Ohio was flooding; the St. Francis, White, Arkansas, Yazoo, Red, Ouachita, and Atchafalaya Rivers were all out of their banks, and new record stages were being established on some of the tributaries. In the flooded areas some of the homes and buildings were completely demolished or severely damaged as wind whipped up large waves on the vast inland bodies of water.

In Missouri, Illinois, Kentucky, and Tennessee private levees were lost and river towns battled seepage and sewer problems and interior



Overtopping of Kaskaskia Island levee

water that sometimes stood several feet deep in low areas. In Louisiana, local interests abandoned an effort to save a private levee south of Jonesville when 20,000 acres of land and 75 homes were inundated as the levee was breached. In the unprotected Yazoo and Red River backwater areas, water was rooftop-high in some places and residents were evacuated as the water continued to inch upward. Near New Orleans main-line levees were threatened by new bank failures and emergency repairs had to be made and setback levees constructed.

Rains continued in the Lower Mississippi River Basin early in May. The river crested at Memphis on 8 May with a stage of 40.4 feet, and as the crest moved southward, weary flood fighters on the lower reaches of the river increased efforts to protect areas that had withstood the earlier crests. The crest reached Vicksburg on 12 May with a stage of 53.1 feet recorded. It was the third highest stage of record.

By 18 May, the river was falling slowly from Cairo to Vicksburg, and the upper Mississippi was reopened to barge traffic for the first time in nearly a month. Cleanup operations had begun on the upper reaches, and backwater was beginning to recede very slowly on some of the lower tributaries. By the last week in May, the river was standing at New Orleans. The Atchafalaya River rose to a record crest of 10.7 feet msl at Morgan City, Louisiana, during the same period. The flood had lasted 77 days at St. Louis and 89 days at Vicksburg.

On the lower reaches, with conditions remaining stable, the Corps began the closure of Bonnet Carré and Morganza on the last day of May. Seepage and sandboils subsided, and the task of repairing and restoring damaged homes was beginning on the lower river. Where damage was particularly heavy, mobile homes were brought in for residents to use until they could rebuild.

The falling stages brought on bank failures in the Louisiana reaches of the river and silt deposited by the flood at the mouth of the river created difficulties for ships entering or departing the Port of New Orleans by way of Southwest Pass.

By mid-June it was determined that the emergency situation had eased, but the lives of thousands of people had been disrupted and preliminary damage estimates amounted to about one billion dollars. Almost 17 million acres of land had been inundated. The devastation caused by the flood was widespread and restoration would be costly.

The long, disastrous flood of 1973 has shown a new generation the awesome power of rivers in flood, especially of the Mississippi River. Corps personnel and local officials who had never seen a major flood quickly became indoctrinated. The hazards of developing floodplain areas were dramatically demonstrated during the flood. The necessity for early completion of the Mississippi River and Tributaries and other Flood-Control Projects was clearly demonstrated.

One of the most notable aspects of the flood was the splendid cooperation that existed between the residents, local officials, and all the State and Federal agencies that became involved in the flood fight. This, notwithstanding the hard decisions that had to be made by the Corps Officers in charge. State and local officials on more than one occasion initially expressed grave concern about some of the Corps' decisions that affected floodways and levees. Later their attitude changed to agreement with, and praise for, the decision makers. Both property damage and human suffering were mitigated to the fullest extent possible by the Corps exercising its maximum emergency authority, and emergency operations were carried out rapidly with sympathetic consideration for the people who were affected by the flood.

Section III

METEOROLOGICAL AND HYDROLOGICAL HISTORY OF STORMS AND FLOODS

GENERAL

The Mississippi River Basin has a total area of 1,246,000 square miles and is naturally divided into seven major basins: Ohio, Upper Mississippi, Missouri, Arkansas, White, Red, and Lower Mississippi. Average annual rainfall over the basin is 30.8 inches and runoff is 7 inches, of which more than 90 percent comes from 56 percent of the drainage basin. In general, the records of tributary discharges prior to 1928 are fragmentary, whereas rainfall records for a larger part of the basin are available back to 1880. The chief sources of rainfall and runoff data are:

"Climatological Data" by U. S. Weather Bureau, monthly publication

"Hydrologic Bulletin" by U. S. Weather Bureau and Corps of Engineers, U. S. Army, monthly publication

"Storm Rainfall in the United States" by Corps of Engineers, U. S. Army, 1946

"Stages and Discharges—Mississippi River Outlets and Tributaries" by Mississippi River Commission, annual publication

"Surface Water Supply of the United States" by U. S. Geological Survey, annual publication

PRECIPITATION

Normal annual precipitation over the entire basin is 30.8 inches and varies according to location from 21.8 inches over the Missouri Basin to 48.5 inches over the Lower Mississippi Basin. The normal monthly precipitation for the basin varies from 1.7 inches in February to 3.8 inches in June and for the tributary basins from 0.7 inch in January for the Missouri to 5.0 inches for the Lower Mississippi in March and the White in May.

Average precipitation, in inches, over the entire basin for the period September 1972 through May 1973 was well above normal for all months with the exception of February 1973. February was slightly below normal. Table 2 shows the total rainfall for March and April to be twice the normal rainfall. As shown in Table 2, precipitation was above normal in the lower portion of the basin from September to December 1972. Total basin precipitation for the 9-month period was about 35 inches, which is 4 inches greater than the average annual basin precipitation.

STORMS

Storms over the tributary basins that produce floods on the lower Mississippi River occur chiefly during January-April and, to a lesser extent, in May and June. Summer storms ordinarily affect smaller areas and are not usually productive of flood stages on the lower Mississippi.

The 1973 flood resulted from a series of small to moderate storms concentrated primarily in the central and west-central portion of the basin. The

TABLE 2

AVERAGE VERSUS OBSERVED PRECIPITATION

	1972								1973											
	Sep		Oct		Nov		Dec		Jan		Feb		Mar		Apr		May		Total	
Subbasin	Avg	Obs	Avg	Obs	Avg	Obs	Avg	Obs	Avg	Obs	Avg	Obs	Avg	Obs	Avg	Obs	Avg	Obs	Avg	Obs
Upper Mississippi River	3.2	4.9	2.3	2.6	2.0	2.6	1.4	1.8	1.4	1.8	1.2	1.4	2.2	5.1	3.0	6.9	3.8	6.5	20.5	33.6
Missouri River	2.6	3.3	1.7	2.0	1.2	2.4	0.8	1.2	0.8	1.4	0.8	0.9	1.6	5.2	2.4	3.2	3.7	4.1	15.6	23.7
Illinois River	3.2	4.9	2.3	2.7	1.9	2.6	1.9	3.4	1.8	1.4	1.7	0.9	2.5	5.7	3.8	5.4	4.1	4.5	23.2	31.5
Ohio River	3.1	5.4	3.0	4.2	3.5	6.6	3.5	5.1	4.2	3.6	3.6	2.6	4.3	7.3	4.2	8.0	4.5	5.9	33.9	48.7
Arkansas River	3.2	3.6	2.5	3.8	2.2	4.0	1.9	2.1	1.9	2.8	1.9	1.6	2.5	8.6	3.5	3.8	4.9	3.8	24.5	34.1
St. Francis River	3.2	6.0	3.1	5.7	4.0	6.6	3.9	6.5	4.5	4.7	4.0	2.8	4.8	8.5	4.4	10.6	4.5	9.1	36.4	60.5
White River	3.1	6.1	3.4	5.5	4.0	7.7	3.9	5.4	4.4	4.8	4.0	3.2	4.6	9.3	4.7	10.5	5.0	6.7	37.1	59.2
Red River	3.0	3.4	3.2	7.6	4.1	5.8	4.1	4.4	4.1	4.1	3.9	3.2	4.1	9.0	5.2	8.1	4.5	3.6	36.2	49.2
Yazoo River	3.1	4.1	2.6	3.5	4.5	8.8	5.3	7.4	5.6	7.7	4.9	4.0	5.8	15.2	5.0	8.2	4.1	5.9	40.9	64.8
Big Black and Southwest Tributaries	2.9	4.1	2.3	3.2	4.2	4.8	5.4	9.1	5.5	6.2	5.2	4.3	6.0	10.9	5.1	9.1	4.7	6.7	41.3	58.4
Lower Mississippi River	--	--	2.9	5.0	4.3	7.2	4.2	7.3	4.7	4.7	4.2	3.7	4.9	10.4	4.5	8.9	4.4	5.7	34.1	52.9
Mississippi River Basin	2.7	3.8	2.3	3.2	2.3	4.0	2.1	2.8	2.1	2.7	2.1	1.7	2.8	6.7	3.4	5.7	4.2	4.8	24.0	35.4

Note: Avg—average; Obs—observed.

largest individual storm systems occurred in March and April. Isohyetal maps for these two months are shown in Plates 1 and 2. The development of the 1973 flood was very similar to that of the 1927 flood in that above normal rainfall began in the fall, proceeded through the winter, and climaxed in the early spring.

DISCHARGE RECORDS

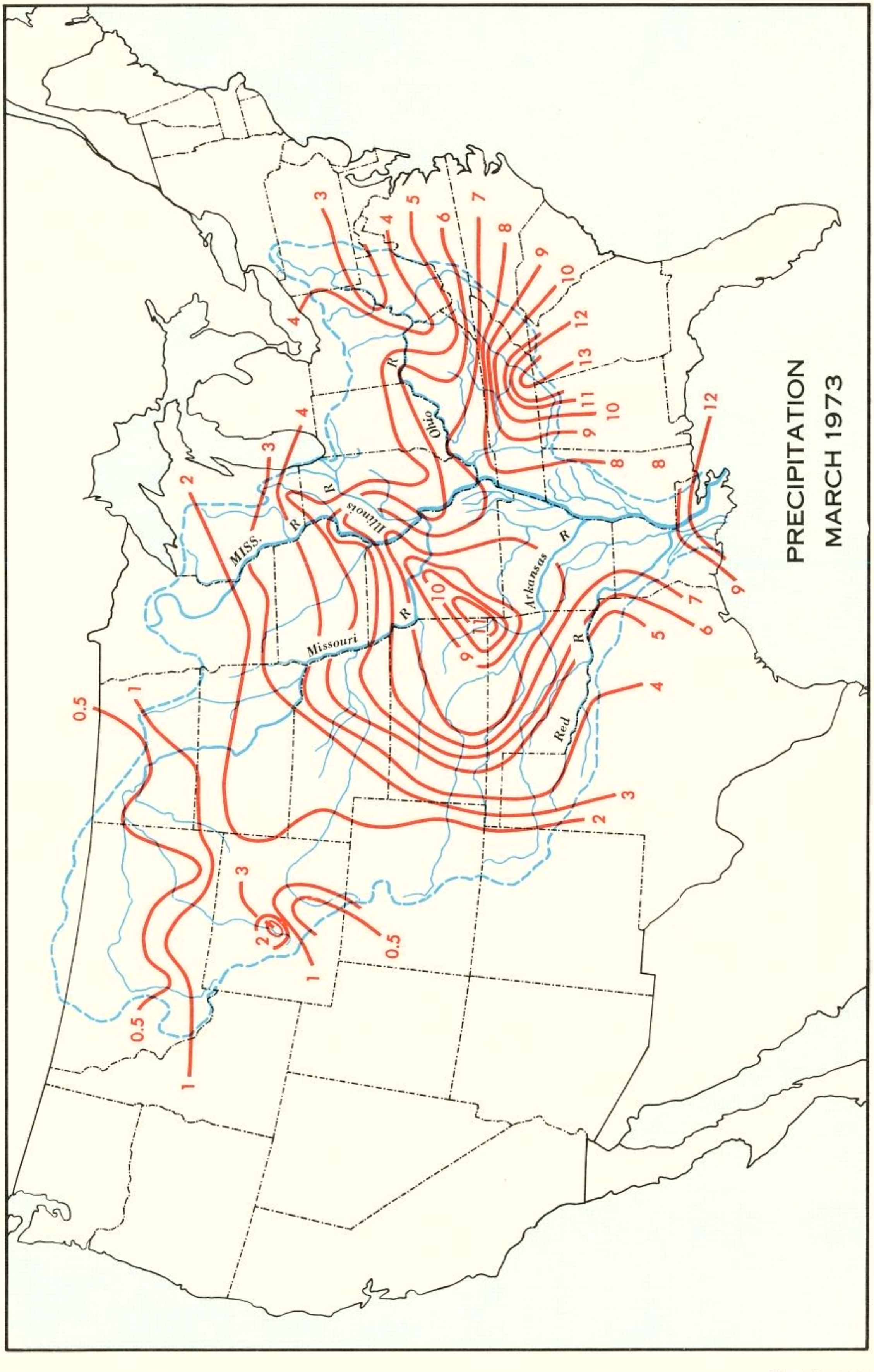
Stream discharge stations within the Mississippi River Basin number in the thousands and their periods of record vary considerably. A few of the stations have records beginning in the 1870's, but in general most of them have records that begin in the late 1920's.

MAXIMUM DISCHARGES

The maximum discharges of record of the Mississippi River and its tributaries vary widely, from about 7,000 cfs per square mile for a 1-square-mile basin in the mountains in North Carolina to about 2 cfs per square mile for the entire basin (1,245,600 square miles) above the latitude of Red River Landing, Louisiana. Table 3 compares the 1973 observed peak discharge with the maximum computed or observed discharges at key gaging stations on the five main tributaries and at five key stations on the Mississippi River.

The 1973 flood was one of the largest on record; however, major discharge records were set only on the upper Mississippi above the Missouri River confluence. Plate 3 shows a comparison between the 1973 observed peak discharges throughout the lower Mississippi River and the Mississippi River Project Flood discharges.

Maximum confined discharges at key stations on the Mississippi River for major Mississippi River floods below St. Louis are shown in Table 4.



PRECIPITATION
MARCH 1973

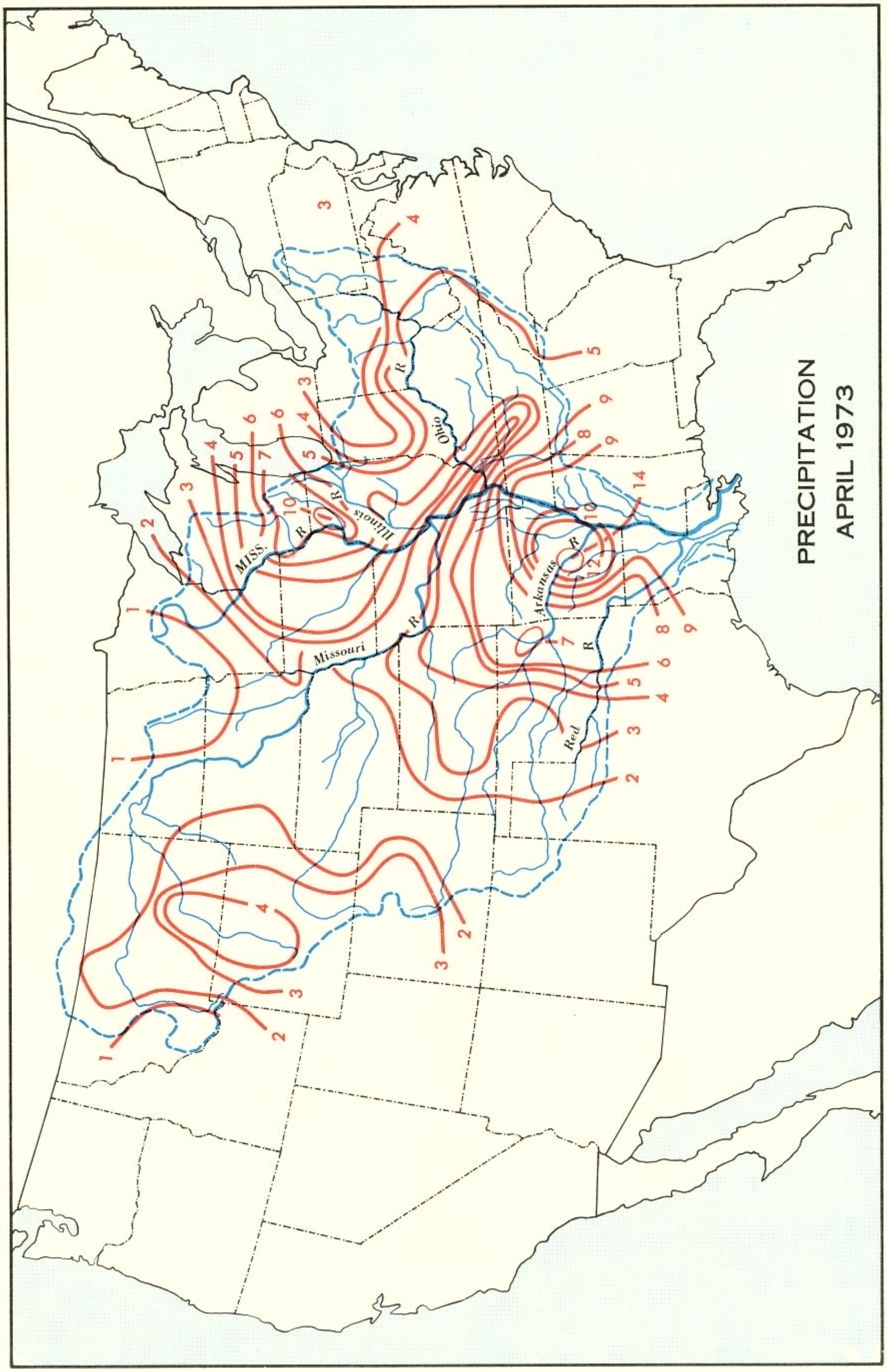
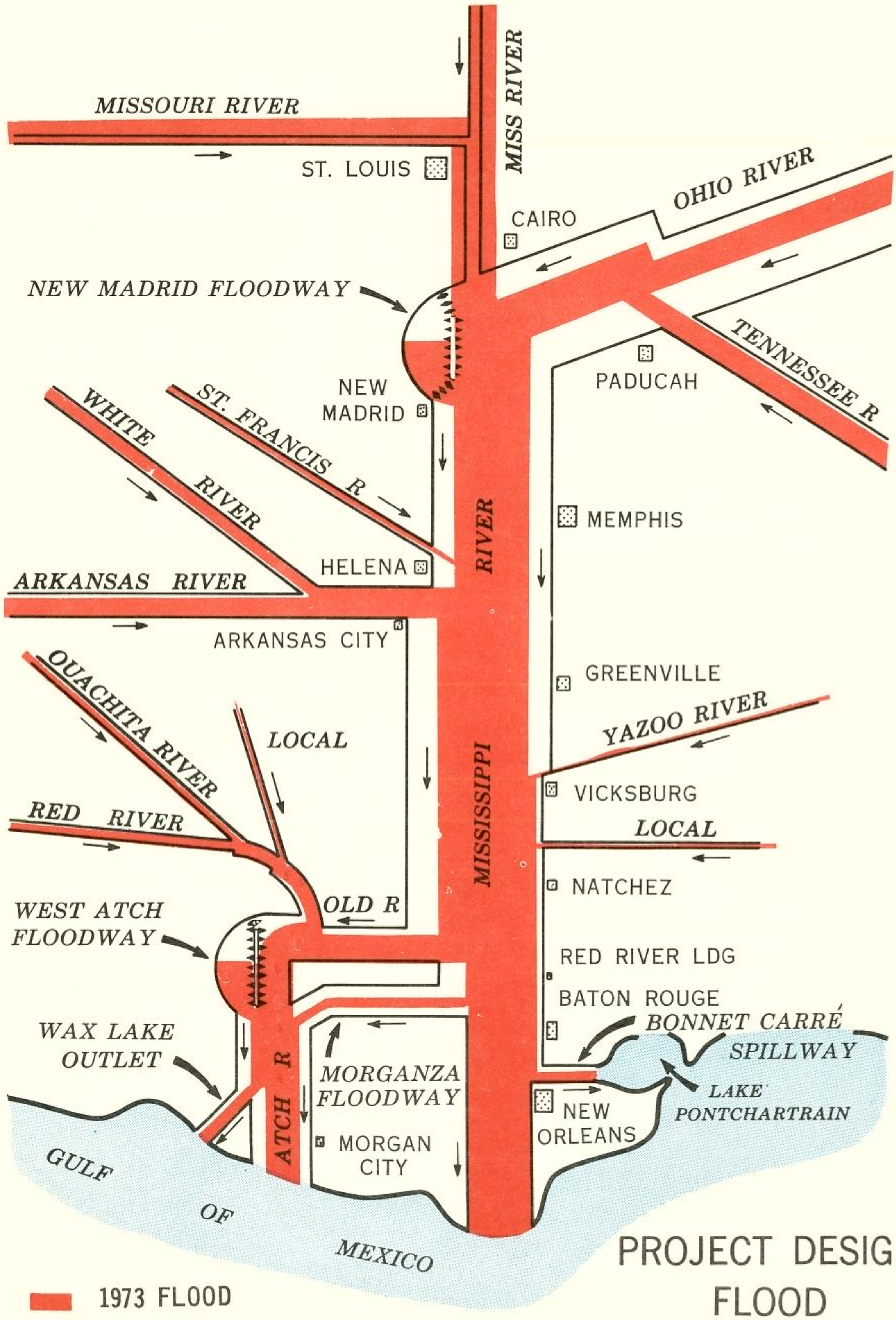

PRECIPITATION
APRIL 1973
Ohio
R
Illinois
R
MISS.
R
Missouri
R
Arkansas
R
Red
R

PLATE 2



PROJECT DESIGN FLOOD

1973 FLOOD

PROJECT DESIGN FLOOD

PLATE 3

TABLE 3

COMPARISON OF MAXIMUM DISCHARGES OF RECORD AND 1973 FLOOD DISCHARGES

River and Location	Maximum Flood of Record Date	Maximum Flood of Record Discharge (cfs)	1973 Flood Date	1973 Flood Discharge (cfs)
Mississippi at Alton, Illinois	May 1943	437,000	Apr 1973	535,000
Missouri at Hermann, Missouri	Jul 1951	676,000[a]	Apr 1973	500,000
Mississippi at St. Louis, Missouri	Jun 1903	1,040,000[b]	Apr 1973	852,000
Ohio at Metropolis, Illinois	Feb 1937	1,850,000	Dec 1972	943,000
Mississippi at Cairo, Illinois	Feb 1937	2,002,000	Apr 1973	1,519,000
Arkansas at Little Rock, Arkansas	Apr 1927	695,000	Apr 1973	329,000
White at Clarendon, Arkansas	Apr 1945	299,000[c]	May 1973	191,200
Mississippi at Arkansas City, Arkansas	Apr 1927	2,615,000[d]	May 1973	1,879,000
Red at Alexandria, Louisiana	Apr 1945	233,000	Apr 1973	142,000
Mississippi at Latitude of Red River Landing	May 1927	2,345,000[d]	May 1973	2,261,000

[a] For the June 1844 flood at Hermann (no discharge records) the flow is estimated to be 890,000 cfs.
[b] For the April 1785 flood at St. Louis (no discharge records) the flow is estimated to be 1,340,000 cfs.
[c] For the April 1927 flood at Clarendon (no discharge records) the flow is estimated to be 440,000 cfs.
[d] Estimated confined under 1939 conditions.

TABLE 4

MAXIMUM CONFINED DISCHARGES

Station	Maximum Discharges, 1000 cfs 1913	1927	1937	1945	1950	1973
St. Louis, Missouri	487	889	374	610	466	852
Cairo, Illinois	1971	1800	2002	1470	1624	1519
Memphis, Tennessee	NA	1744	2020	1468	1586	1633
Arkansas City, Arkansas	2005	2615	2188	1911	1791	1879
Vicksburg, Mississippi	NA	2278	2060	1922	1876	1962
Latitude of Red River Landing	1810	2345	1896	2123	2054	2261

NA - Not available.

COMPARISON OF 1927 AND 1973 FLOODS

Stage hydrographs showing the 1973 floods and other significant years on the Mississippi River at St. Louis, Cairo, Memphis, Arkansas City, Vicksburg, and Red River Landing are shown in Plates 4 through 9. Table 5 shows a comparison between the peak flows at these same locations for the 1927 and 1973 floods.

TABLE 5

MAXIMUM DISCHARGES ON MISSISSIPPI RIVER
FOR 1927 AND 1973 FLOODS

Location	1927 Flood[a] Discharge (cfs)	1973 Flood Discharge (cfs)
St. Louis, Missouri	889,000	852,000
Cairo, Illinois	1,800,000	1,519,000
Memphis, Tennessee	1,744,000	1,633,000
Arkansas City, Arkansas	2,615,000	1,879,000
Vicksburg, Mississippi	2,278,000	1,962,000
Latitude of Red River Landing	2,345,000	2,261,000

[a] Estimated confined under 1939 conditions.

MONTHLY AND ANNUAL RUNOFF

The average annual runoff for the entire basin is 480 million acre-feet and expressed in terms of depths over the drainage basin is 7.1 inches. This runoff is equivalent to a mean annual discharge of 657,000 cfs. The minimum annual runoff is 249 million acre-feet (3.7 inches or 341,000 cfs) and the maximum is 807 million (11.9 inches or 1,106,000 cfs). The average monthly runoff for the basin is 40 million acre-feet (0.6 inch or 657,000 cfs) and varies from a minimum monthly runoff of 6 million acre-feet (0.09 inch or 105,000 cfs) to a maximum monthly runoff of 138 million acre-feet (2 inches or 2,223,000 cfs).

The runoff in inches for the entire basin above the latitude of Red River Landing for the period of December 1972 through May 1973 and the minimum, average, and maximum monthly runoff for the basin are shown in Table 6. The runoff for the months shown was far above the average and closely approached the maximum. Plate 10 shows the rainfall for the entire Mississippi Basin in percent above normal from September 1972 through May 1973.

The maximum annual flow of record for the Mississippi River occurred in 1927, and the minimum annual flow occurred in 1934.

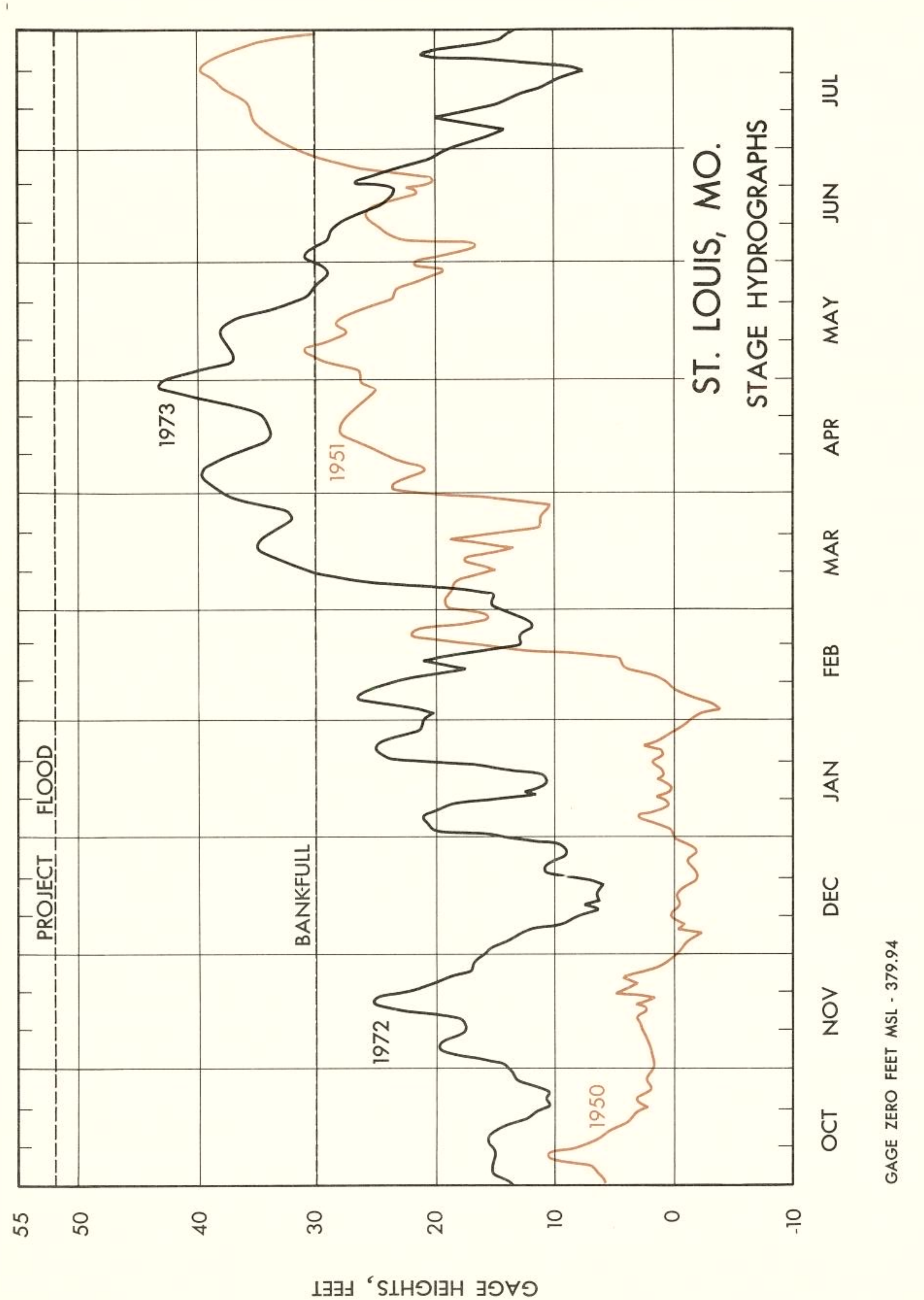
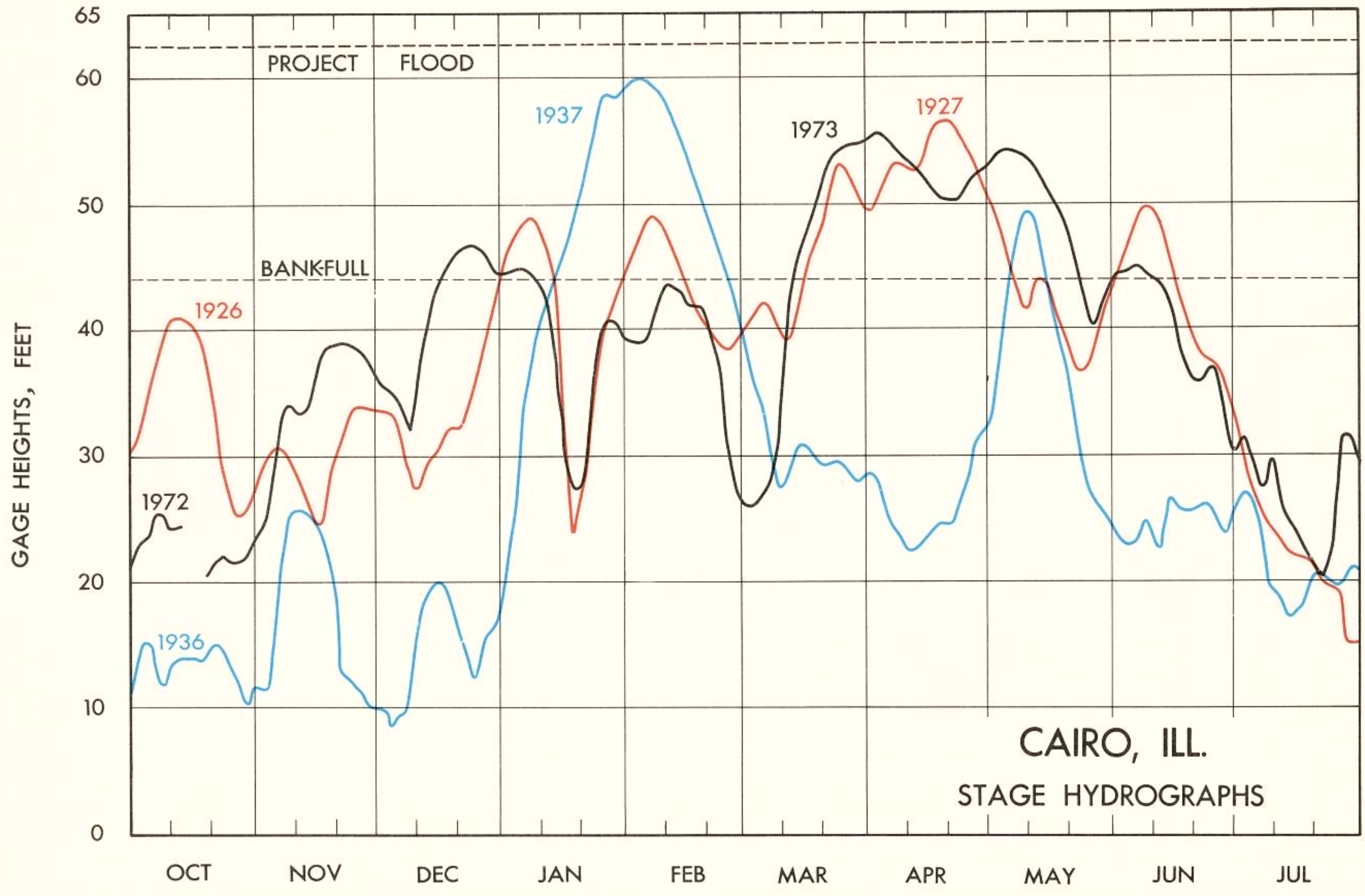
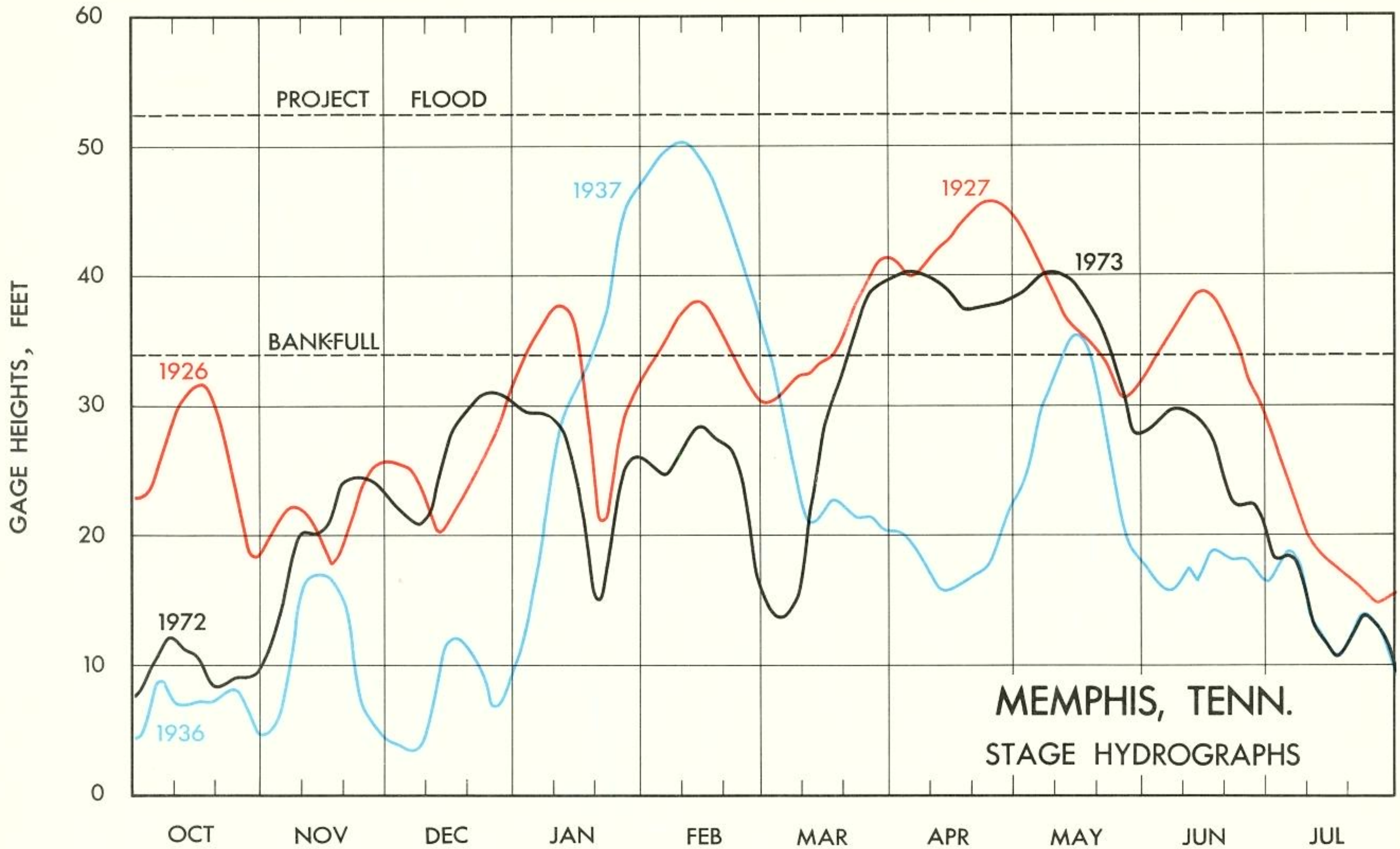

ST. LOUIS, MO.
STAGE HYDROGRAPHS
PROJECT FLOOD
BANKFULL
1972
1973
1950
1951
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
55
50
40
30
20
10
0
-10
GAGE HEIGHTS, FEET
GAGE ZERO FEET MSL - 379.94

PLATE 4



GAGE ZERO FEET MSL - 270.47



GAGE ZERO FEET MSL - 183.91

PLATE 6

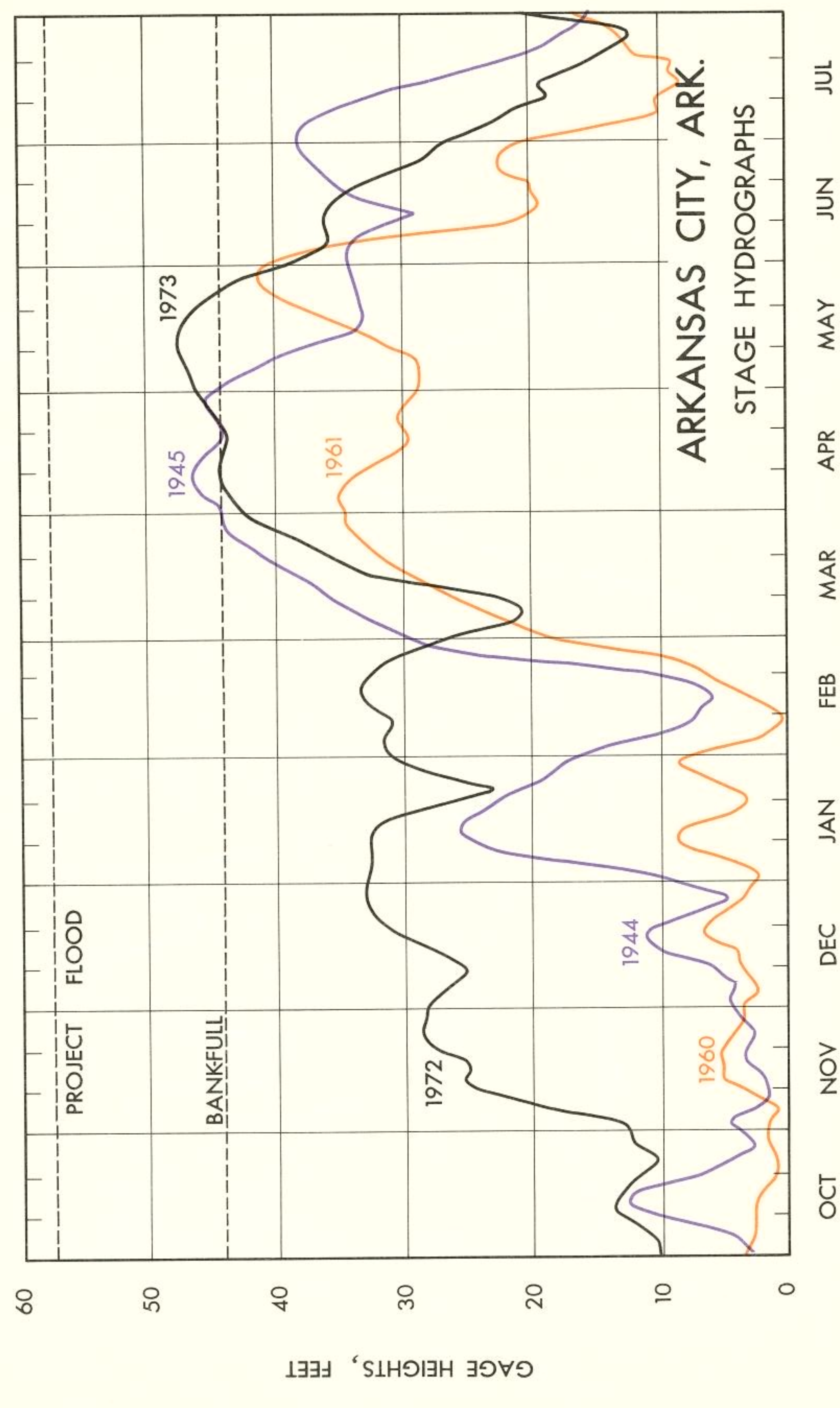
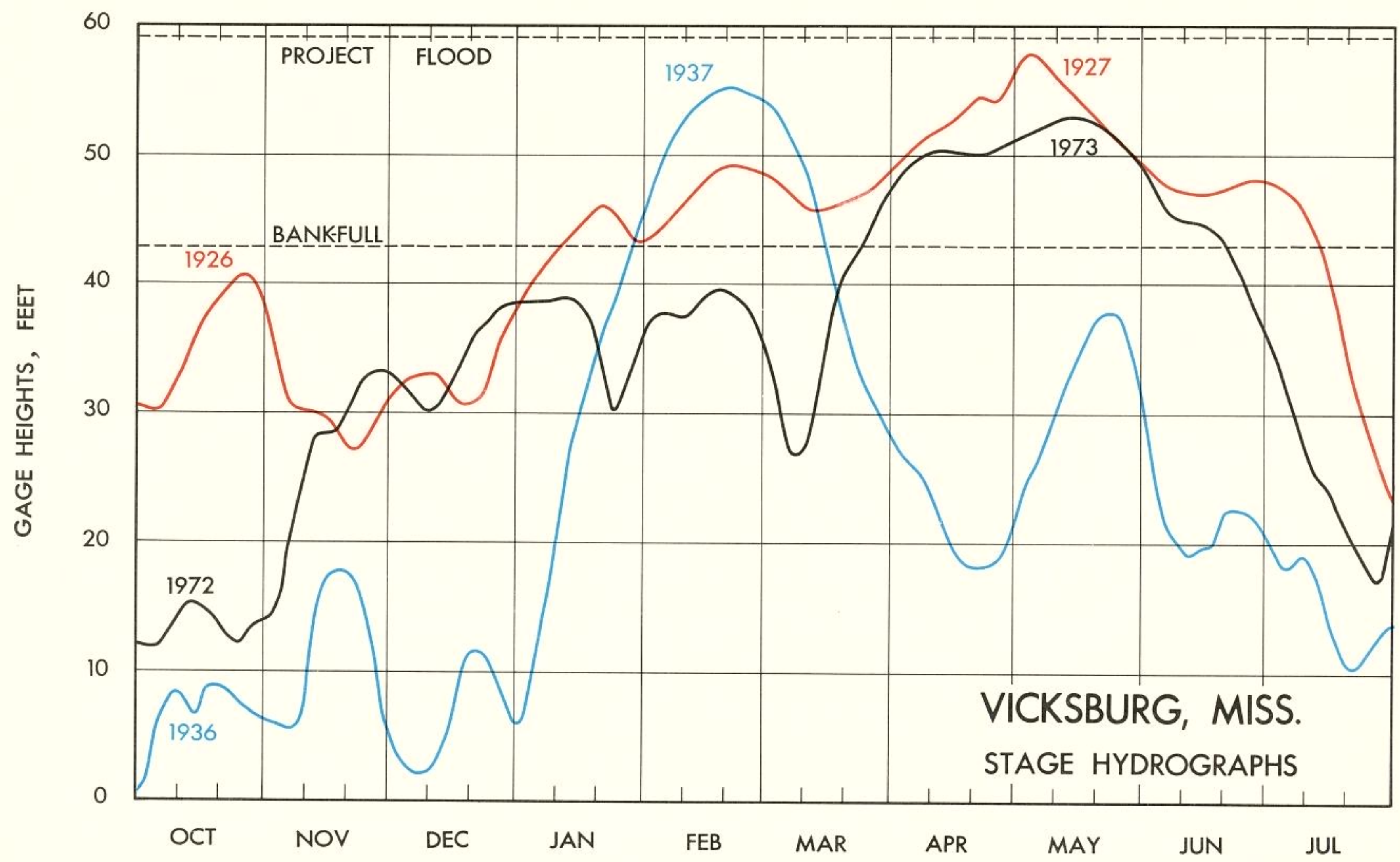
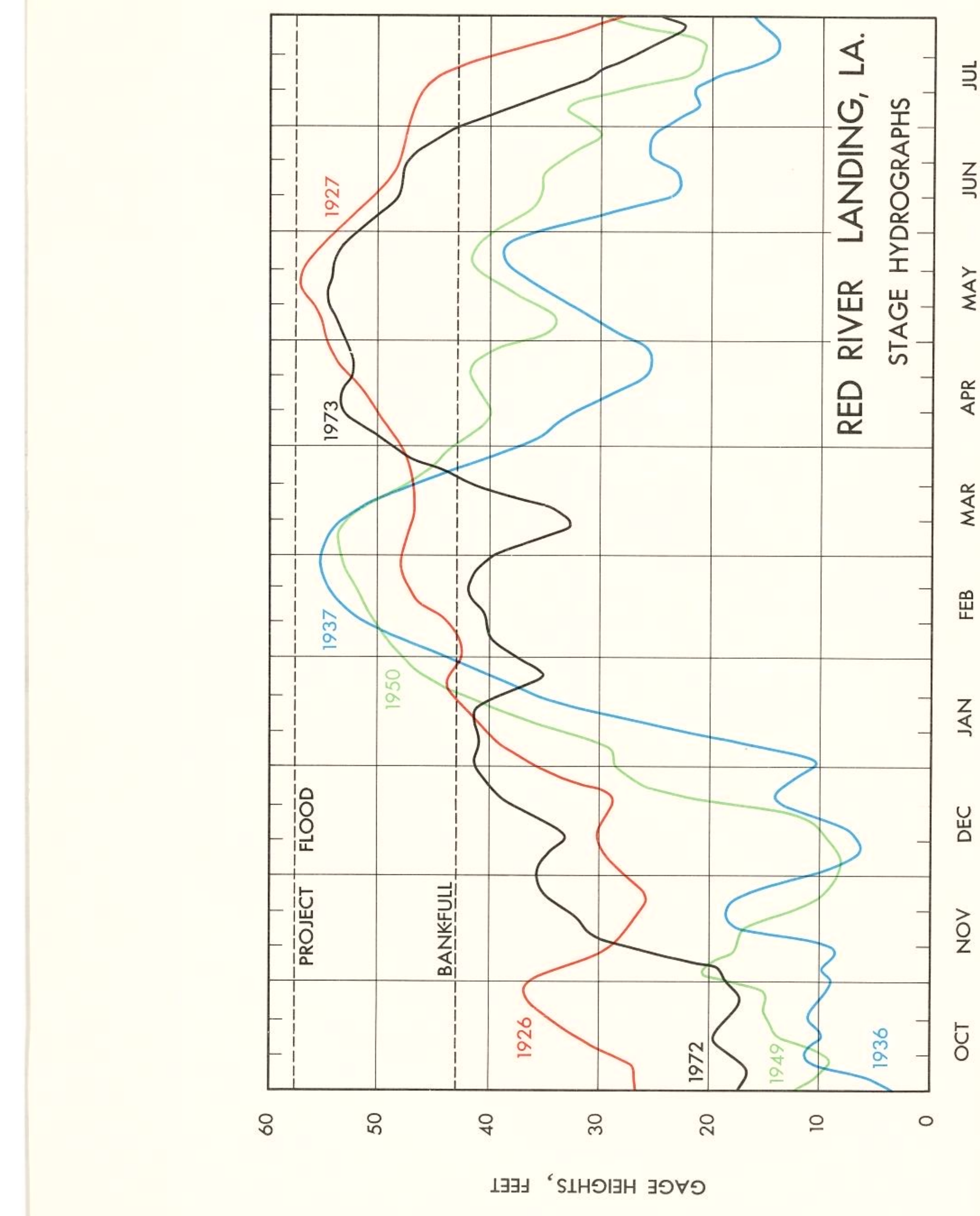

ARKANSAS CITY, ARK.
STAGE HYDROGRAPHS
PROJECT FLOOD
BANKFULL
1972
1973
1944
1945
1960
1961
OCT NOV DEC JAN FEB MAR APR MAY JUN JUL
0 10 20 30 40 50 60
GAGE HEIGHTS, FEET
GAGE ZERO FEET MSL - 96.66

PLATE 7



GAGE ZERO FEET MSL - 46.23


RED RIVER LANDING, LA.
STAGE HYDROGRAPHS
PROJECT FLOOD
BANKFULL
1926
1927
1936
1937
1949
1950
1972
1973
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
0
10
20
30
40
50
60
GAGE HEIGHTS, FEET
GAGE ZERO FEET MSL - 3.49

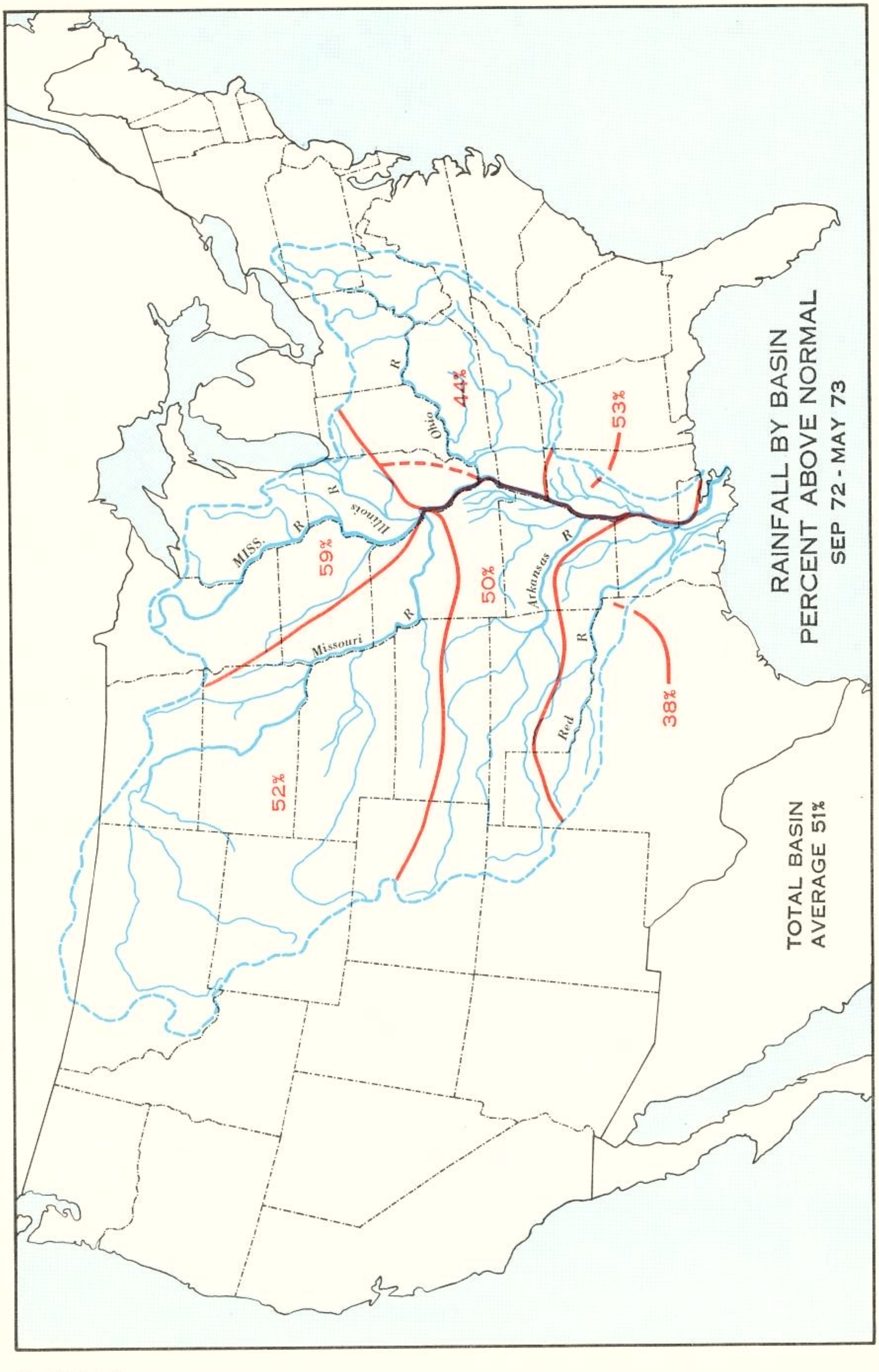

RAINFALL BY BASIN
PERCENT ABOVE NORMAL
SEP 72 - MAY 73
TOTAL BASIN
AVERAGE 51%
44%
53%
59%
50%
52%
38%
Ohio
R
Illinois
R
MISS.
R
Missouri
R
Arkansas
R
Red
R

PLATE 10

TABLE 6

MINIMUM, AVERAGE, AND MAXIMUM MONTHLY RUNOFF IN INCHES

(D. A. = 1,245,600 square miles above latitude Red River Landing)

Month	Period of Record			1973
	Minimum	Average	Maximum	Flood
December	0.12	0.41	0.95	1.08
January	0.14	0.60	1.19	1.20
February	0.18	0.69	1.59	1.08
March	0.39	0.88	1.57	1.12
April	0.49	0.98	1.82	1.73
May	0.40	0.97	2.03	1.97
Total	1.72	4.53	9.15	8.18

CONTRIBUTION OF FLOW

The major portion of the average mean monthly flow at St. Louis, Missouri, is from the upper Mississippi River, except during June and July when there is a slight excess flow from the Missouri River. The contribution of the upper Mississippi reaches a maximum of approximately 65 percent in January. Contributions by the Missouri and upper Mississippi Rivers at St. Louis during the 1973 flood period were almost equal.

The average mean monthly contribution of flow from the Ohio River predominates from December through April, reaching a maximum of approximately 76 percent in January. The average mean monthly contribution of flow from the Mississippi River above Cairo is greater from June through October, reaching a maximum of about 66 percent in July. The 1973 flood in the Lower Valley was heavily influenced by the Mississippi River flow above Cairo, as evidenced by the fact that Ohio River contributions were below average for the period January through May 1973.

The average mean monthly flow from the Arkansas and White Rivers varies from a minimum of approximately 11 percent of the discharge at Arkansas City in July to a maximum of about 17 percent in June. For the 1973 flood, the contribution from the Arkansas and White Rivers was above average in February, March, April, and May. For the month of March, the 1973 contributions were almost double the average. This above-average inflow added 2 to 3 feet of stage below Arkansas City on the Mississippi River.

The average mean monthly flow from the Red and Ouachita Rivers varies from a minimum of about 4 percent of that at latitude of Red River Landing in July and August to a maximum of approximately 11 percent in January. The contribution of the Red and Ouachita Rivers to the 1973 flood was average to below average. The 1973 flood contribution and average contributions are compared in Table 7.

TABLE 7

PERCENT CONTRIBUTIONS TO AVERAGE MONTHLY MISSISSIPPI RIVER FLOW

Month	Missouri at St. Louis		Ohio at Cairo		Arkansas & White at Arkansas City		Red & Ouachita at Latitude of Red River Landing	
	Period of Record	1973	Period of Record	1973	Period of Record	1973	Period of Record	1973
December	36	40	65	80	13	10	9	4
January	35	42	76	59	13	13	11	6
February	37	45	73	56	12	15	10	7
March	39	49	66	54	12	22	9	11
April	40	48	57	47	14	18	8	8
May	40	34	48	44	16	19	9	9

RESERVOIRS

At the time of the 1973 flood, numerous flood-control and multipurpose reservoirs were in operation. The majority of these reservoirs are in tributary, basin-wide, water-resource-development projects that are designed to provide a large measure of benefit to local protection projects in tributary valleys, but they also provide benefits along the main stem of the Mississippi River by reducing the magnitude and frequency of floods. It is estimated that operation of reservoirs in the Missouri River and upper Mississippi River valleys combined to reduce stages at St. Louis about 2 feet at the crest of the 1973 flood. The reservoirs on the Ohio, Tennessee, and Cumberland Rivers were operated to reduce stages at Cairo, Illinois, about 3.6 feet for the April crest and slightly over a foot for the May crest. Stage reductions at Cairo, including effects of the Mississippi River to St. Louis, were estimated to be 4.6± feet for the April crest and 1.5± feet for the May crest. This is equivalent to a 265,000-cfs reduction in the peak discharge at Cairo, Illinois. The estimated reduction in stage at Vicksburg, Mississippi, was 2.5± feet for the April crest and 1.5 to 2.0 feet for the May crest. This is equivalent to 175,000 and 105,000 to 140,000 cfs, respectively. Table 8 shows a comparison between the 1973 observed peak discharges throughout the lower Mississippi River and what the 1973 peak discharges would have been without the existing reservoirs in the basin.

Many reservoirs experienced record elevations in flood-control pool, and by May 1973 the majority of the major reservoirs had utilized 75 percent or more of flood-control pool capacity.

Most of the major reservoirs in the basin are located in areas within the jurisdiction of the Ohio River Division, Missouri River Division, North Central Division, and Southwestern Division. All Divisions cooperated to the fullest extent possible to operate their respective reservoir systems to effect maximum reduction of crest stages.

TABLE 8

MAXIMUM DISCHARGES FOR 1973 FLOOD

River and Location	Maximum Discharge (cfs) Observed	Maximum Discharge (cfs) Unregulated [a]
Tributaries:		
Missouri River, Hermann, Missouri	500,000	560,000
Ohio River, L&D No. 51	570,000	610,000
Ohio River, L&D No. 52	920,000	1,070,000
White River, Clarendon, Arkansas	191,200	220,000
Arkansas River, Little Rock, Arkansas	329,000	490,000
Yazoo River, Below Steele Bayou	75,000	130,000
Ouachita River, Monroe, Louisiana	87,900	87,900
Red River, Alexandria, Louisiana	142,000	167,000
Mississippi River:		
Alton, Illinois	535,000	560,000
St. Louis, Missouri	852,000	910,000
Cairo, Illinois	1,519,000	1,784,000
Memphis, Tennessee	1,633,000	1,883,000
Arkansas City, Arkansas	1,879,000	2,050,000
Vicksburg, Mississippi	1,962,000	2,102,000
Natchez, Mississippi	2,017,000	2,150,000
Latitude of Red River Landing	2,261,000	2,391,000

[a] Estimated maximum discharge with no reservoirs in the Mississippi River Basin.

Section IV
EMERGENCY ACTIVITIES

CORPS OF ENGINEERS ACTIVITIES

GENERAL

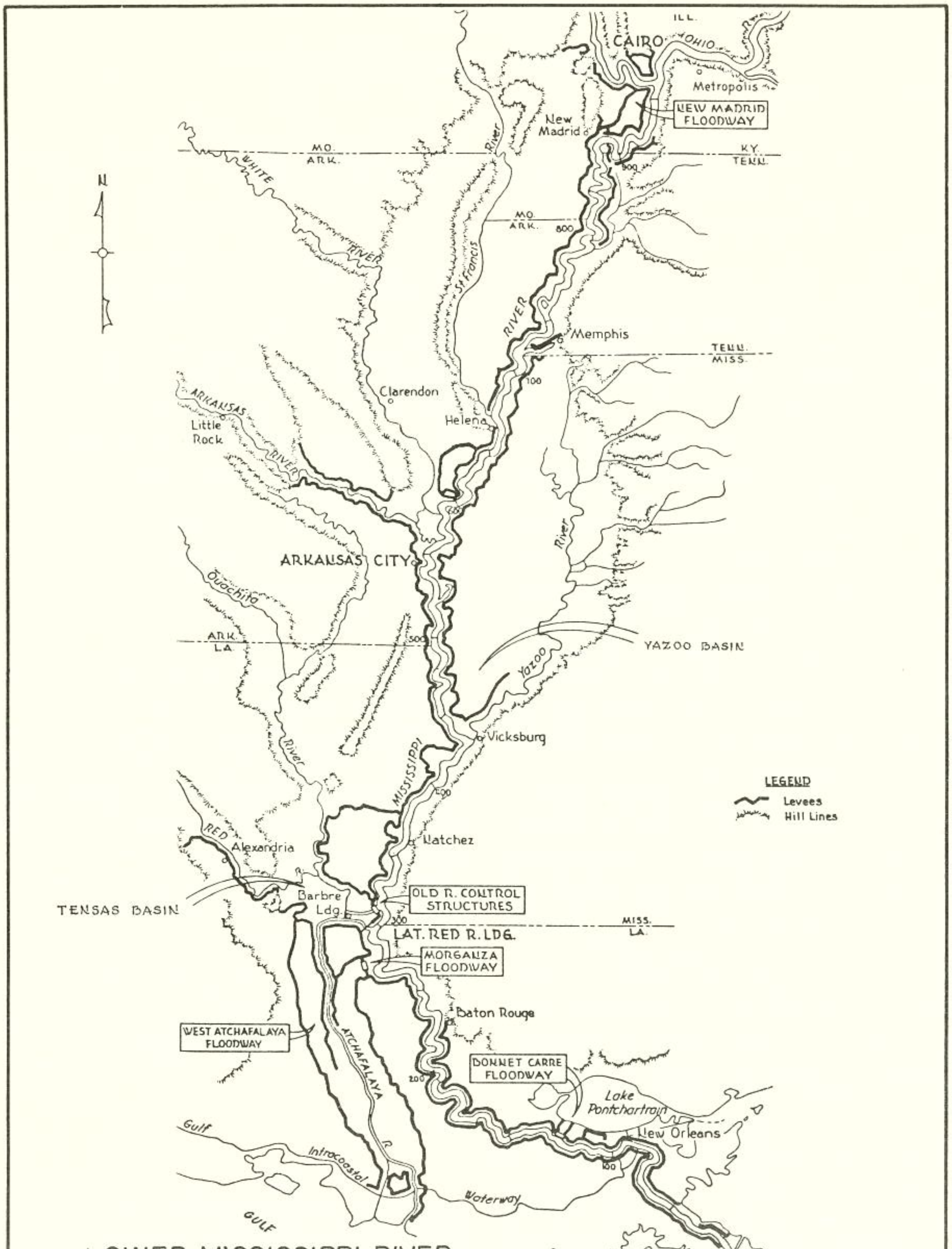
Under the statutory authority of Public Law (PL) 84-99 the Corps of Engineers has a continuing responsibility to support local interests in all phases of flood fighting. In order to carry out its responsibilities, the Corps maintains a complete flood emergency operation plan which includes every echelon of Corps command, from the Office, Chief of Engineers, to remote field offices. It includes organization charts with assignments of key personnel by name as well as the availability of Corps construction and support equipment and supplies. Plans include support by other Corps Divisions and private contractors. An advance preparation program of planning and training in both technical and administrative fields is standard procedure.

Increased emphasis was put on advance preparation measures in the LMVD in January and February of 1973 because of the abnormal high stages of the Mississippi River during the period of October-December 1972. A Division-wide flood-fight exercise had already been planned for February 1973; however, more emphasis was placed on the exercise because of the high-water situation. Another advance preparation measure taken by the Division Engineer, LMVD, was to direct his District Engineers to make a thorough field inspection of all major flood-control works and to conduct a trial operation of the major structures that are operated and maintained by the Corps. Plate 11 shows the location of the principal flood-control works in the lower Mississippi River.

From the first of March until mid-June 1973, Corps personnel were engaged in emergency operations in most areas of the 2300-mile-long Mississippi River Basin, at a cost of approximately $50,000,000. Some relatively new methods and materials were used in the flood fight, and they are described later in this section. The Corps provided 14,000,000 sandbags, 6,800 rolls of polyethylene, and 616 portable pumps for the flood-fight effort. There were 45,300 persons evacuated from flooded or flood-threatened areas. Corps of Engineers personnel involved in the flood effort numbered 2,217, and approximately 15,600 man-days of work was performed by the Corps for the Federal Disaster Assistance Administration (FDAA). In the LMVD where the flood fight was most severe LMVD personnel were supplemented by 289 Corps employees from other Divisions. PL 84-99 also authorizes the repair or restoration of any flood-control work threatened or destroyed by flood determined to be necessary by the Corps of Engineers for the adequate functioning of the work for flood control. During and immediately following the flood, the Corps of Engineers repaired private and Federal flood-control works in the LMVD at a cost of approximately $92,000,000. The required additional funds were appropriated by Congress and were handled expeditiously at all levels within the Corps.

ACTIVITIES BY BASIN

A brief account of Corps activities throughout the Mississippi River Basin is given below. More detailed accounts are given in the appendixes, which are available as indicated in Section I under Purpose and Scope, page 1.



LOWER MISSISSIPPI RIVER
MAIN STEM
LOCATION OF
FLOOD CONTROL STRUCTURES

PLATE 11

Upper Mississippi River Basin

Flooding on the Upper Mississippi River Basin (above Cairo, Illinois) was severe and of long duration. However, no flooding to any great extent occurred above the Minnesota-Iowa state line, and only $12,000 was spent in the state of Wisconsin on the flood effort.

Mississippi River tributaries in the states of Iowa and Illinois began flooding the first of January 1973, because of ice jams and above normal stream flow. Flooding continued through 1 June because of heavy rainfall, and Corps personnel were dispatched into the field to assist local interests in flood-fight operations. The tremendous effort put forth by local interests with Corps assistance was not enough in most cases. The private levees of the upper Mississippi, above Grafton, Illinois, were for the most part breached or topped, and tremendous damages occurred up and down the river.

Missouri River Basin

The Missouri River Basin contributed heavily to the flooding on the lower Mississippi River, but floods of record proportions were not reached. The maximum discharge at Hermann, Missouri, was 500,000 cfs compared with a record discharge of 892,000 cfs recorded in 1844. Corps flood-fight activities were limited to the lower 250 miles of the Missouri River; they were begun on 6 March and lasted through 9 April. Corps personnel were dispatched to gather stream data, patrol levees and roadways, establish liaison with local interests, and distribute sandbags as needed.

Illinois River Basin

Early in March 1973, Corps personnel were deployed into the Illinois River Basin where they provided assistance and advice to local interests. The Illinois River Basin consists of hilly farmland terrain with a limited floodplain, most of which is protected by local interest levees. A concentrated effort was required by local interests, Corps of Engineers, and volunteers to prevent excessive damage to the levee system. The river was closed to commercial traffic during two different periods for a total of 37 days. This closure was to prevent wave wash damage to the levees and riverside structures. The Red Cross established a flood-fight center at Grafton, Illinois, near the confluence of the Illinois and the upper Mississippi Rivers, and it became a center of activity for other flood-fight organizations. This center was eventually staffed by representatives from the Red Cross, Corps of Engineers, Jersey County Sheriff's Office, Illinois Conservation Department, and the Illinois National Guard. The Corps was the prime contributor of equipment and tools used to fight the flood. Over 30 pumps, 1.1 million sandbags, 350 rolls of plastic, 400 life preservers, and other equipment were ultimately committed to the emergency action. Of the 18 private levees along the lower portion of the Illinois River, 5 were overtopped, 6 were breached, and the remaining 7 were saved.

Ohio River Basin

The first of the moderate flooding on the Ohio River in the 1972-1973 high-water season began in December 1972. Barkley and Kentucky Reservoirs were operated to lower stages on the lower Ohio and lower Mississippi Rivers. From January through June 1973, heavier flooding occurred. From 15 through 17 March, heavy rains fell over the southern portion of the Ohio River Basin, and during the period 26-31 March more moderate rains came. Flood-fight activity was light in the lower portion of the Ohio River Basin. The Ohio River contributed significantly to the flood flows on the lower Mississippi; however, it did not contribute a proportionate share of the water that might be expected during a flood of the magnitude experienced during the spring of 1973.

Arkansas River Basin

Emergency activities in the headwaters of the Arkansas River Basin were extremely limited with only minor efforts being required. Beginning on

Fabius drainage district, north of pumping station on Fabius levee, looking upstream, 23 April 1973

Sny Island drainage district, burlap used to stop erosion caused by seepage on land side of levee upstream from pump station No. 1, looking downstream, 28 April 1973

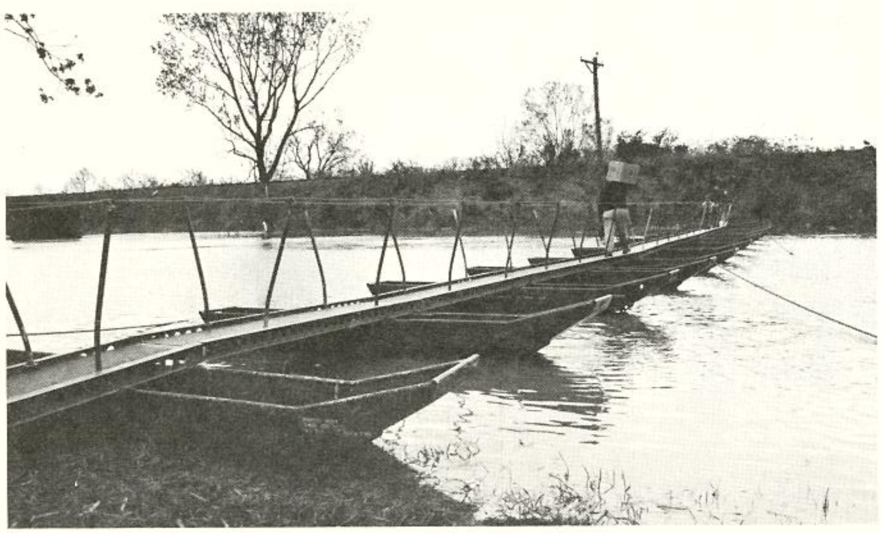
Hannibal, Missouri, looking east on Highway 36 from foot of Mark Twain Memorial Bridge toward East Hannibal, Illinois, 28 April 1973

South end of Cape Girardeau, Missouri

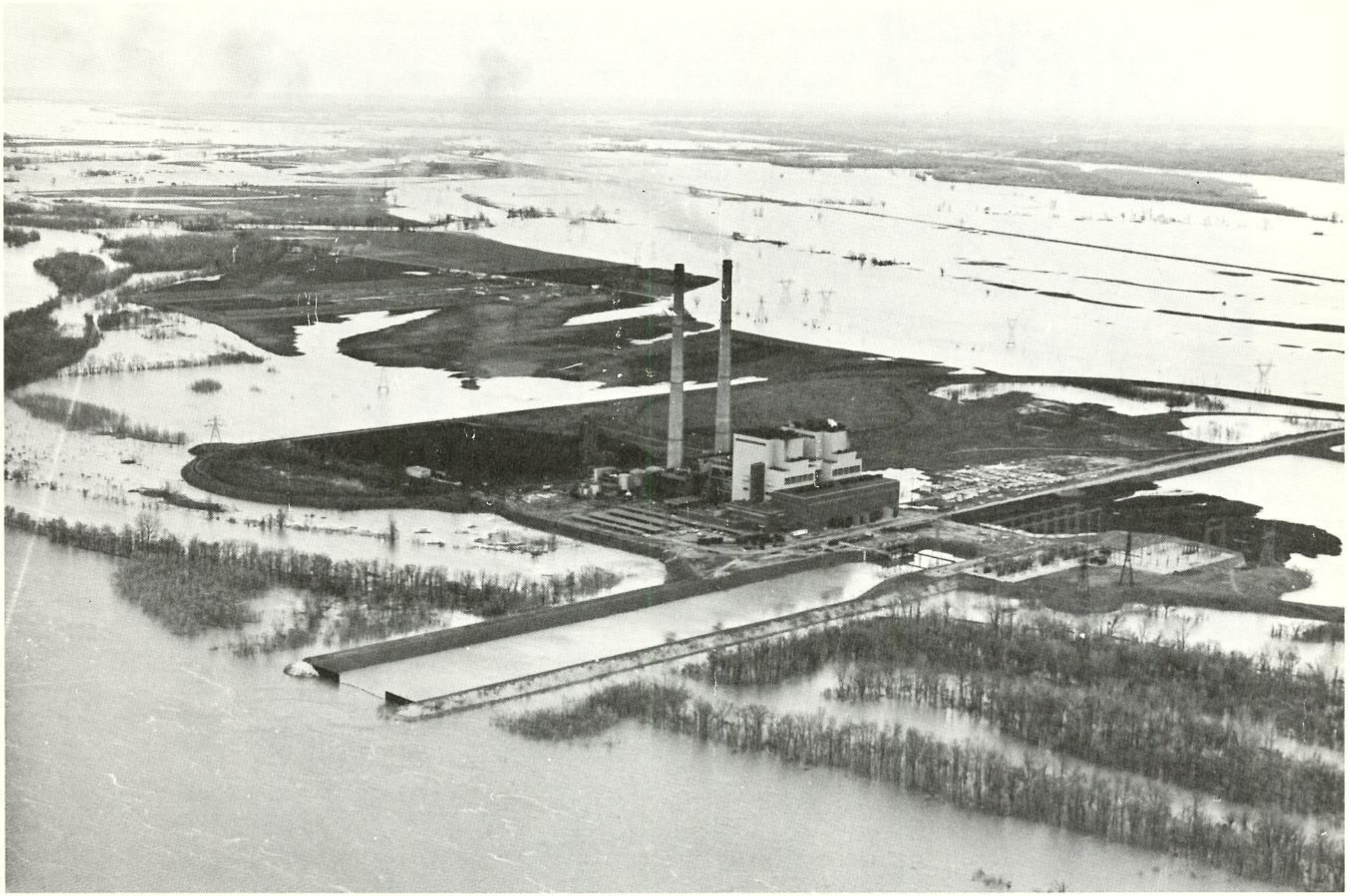
Commerce, Missouri

Highway 94, West Alton, Missouri

Dislocated residence, Chouteau Island



Emergency pontoon foot bridge assembled by Army personnel from Fort Leonard Wood, Missouri



Union Electric Powerplant, 3 miles downstream from Portage Des Sioux on Mississippi River. Missouri River in background

Cedar City, Missouri, and Jefferson City, Missouri (right bank), Missouri River mile 144, 5 June 1973

Kampsville Ferry Landing closure, Highway 108 and Eldred levee, 26 April 1973

Highway 100, South Main Street, Kampsville, Illinois, 28 April 1973

23 April, levees were patrolled between Fort Smith and Pine Bluff. Minor flood-fight problems developed in North Little Rock, Arkansas, where a pumping station failed to operate properly. On 24 April, when flood flows reached 300,000 cfs at Little Rock, Locks 8 and 9 were closed. On 25 April, Locks 3 through 7 were closed to traffic. Locks 7 through 9 were reopened to traffic on 27 April, and 3 through 6 were reopened on 28 April. Below Pine Bluff the levees were patrolled from 2 March to 15 June. No major problems were encountered.

St. Francis River Basin

Flooding in the St. Francis River Basin was not significant until 16 April when torrential downpours pelted the area. In some areas as much as 8 inches in 8 hours were reported unofficially. The cities of Paragould, Piggott, Marmaduke, Madison, and Wynne, Arkansas, were all under threat of flooding during this period. Corps employees provided technical advice and sandbags, pumps, and other materials to local interests. No levee failures were observed, and flood damage was light.

White River Basin

Corps employees began levee patrols and other emergency operations on the White River above Georgetown, Arkansas, on 20 April 1973, and on the lower White River below Georgetown on 23 April 1973, providing assistance as required by local interests. This consisted mainly of providing advice and equipment in the form of sandbags and pumps. None of the project levees appeared to be in any danger at any time during the 1973 flood. Some basement flooding due to seepage and sewer problems in populated areas occurred; however, damages were very light.

Ouachita River Basin

Major flood activities in this basin were limited to the lower reaches of the river. Some subdivisions north of Monroe, Louisiana, required sandbagging and pumping to protect residences. The town of Jonesville, Louisiana, which is located in the Red River backwater area was protected from flooding by a Corps levee. Like most communities in recent years, Jonesville has grown, and outside the protected areas there are several industries, a hospital, and residential areas that were endangered by flooding. A Louisiana Department of Public Works levee was held as long as possible to protect the outlying Jonesville area. On 18 April it became apparent that that levee would be overtopped, and construction was begun on an emergency ring levee around an area just west of Jonesville, to provide protection to the previously mentioned hospital, industries, and residential areas. Corps of Engineers personnel and equipment assisted in the construction of the ring levee. The levee functioned well and prevented flooding of the area.

Some difficulty was experienced with the Bayou Cocodrie floodgate, a five-gated structure in the Red River backwater levee. At times the Red River was as much as 10.4 feet higher than the impounded water. Leakage developed through two of the gates, but was successfully stopped by Corps emergency operations. On 3 May 1973, Corps officials decided to raise 36 miles of Red River backwater levees 1.2 feet to protect against anticipated wave wash as the level of the backwater continued to rise. Where borrow material was available a small levee referred to as a "potato ridge" was constructed by borrowing material from the backside of the levee and placing it on the crown. In some cases, the levee section was not sufficient for this method, and approximately 7000 feet of levee was raised by the use of sandbags. Twenty-three miles of levee was protected with polyethylene film to afford added protection from wave wash. One of the larger pumping operations of the flood took place in the Bayou Cocodrie area. With the sump gates closed, impounded water from interior drainage was steadily rising. A total of twenty 12- and 16-inch

Arkansas River flooding, south of Wichita, Kansas, Holiday Lakes area

White River flooding in vicinity of Crossroads, Arkansas pumps were placed in service on 28 May, and pumping continued until 21 June 1973. During this period a relatively constant water level was maintained.

Red River Basin

No significant emergency activities were required in the Red River Basin above the Texas-Arkansas state line. The lower Red River, below Texarkana, however, was a major flood activity area. Widespread rainfall caused prolonged high-water and backwater flooding in many areas. Bank caving was accelerated, and migration of the river threatened to breach the levee system at several locations. Levee setbacks were required in three different locations along the Red River near the towns of Abbington, Moncla, and Lake End, Louisiana. In seven different locations, emergency revetments were placed on the banks of the Red River in lieu of emergency levee setbacks. Since regular revetment work was scheduled for these locations in the future, regular project funds were utilized. Some additional costs were involved due to the emergency nature of the construction. Backwater flooding in the lower Red River area was extensive and severely affected thousands of acres of farm and timber lands. Many unincorporated communities scattered throughout the area where the lands are not protected by levees were flooded.

Backwater flooding in lower Red River area, Louisiana

Yazoo River Basin

The 1973 flood fight in the Yazoo River Basin began on the night of 15 March 1973, when an 8-inch rain fell. Local interest levees along Big Sand and Pelucia Creeks east of Greenwood, Mississippi, were crevassing under the heavy pressure thereon. Within 3 hours after the Mayor of Greenwood requested assistance, Corps of Engineers forces and equipment began removal of an earth plug in Fort Pemberton cutoff, allowing a portion of the Yazoo River flow to bypass the city of Greenwood. Corps personnel began issuing sandbags and assisting local interests in the flood fight on 16 March. Repairs to the crevassed local levees under PL 84-99 funding and authority began as soon as possible, and Corps officials loaned pumps as soon as they were available. On 31 March the FDAA gave the Corps the mission of pumping water from the flooded subdivisions. The work was essentially completed on 12 April. On 31 March the decision was made to raise 28 miles of project levees at Greenwood and 4-1/2 miles of local levees at Belzoni on the possibility that these levees could be overtopped by April rains. These projects utilized plywood flashboards and earth embankment and were completed in about two weeks.

Big Black River and Southwest Tributaries Basins

No Corps of Engineers emergency activities were required in these basins.

Lower Mississippi River, Main Stem

In the Lower Mississippi Basin, which includes all or part of the tributary basins below Cairo, Illinois, flood protection is dependent upon the proper functioning of the Mississippi River and Tributaries (MR&T) Flood Control Project. An insight into the Corps of Engineers emergency activities necessary to the proper functioning of the MR&T Project and the thinking behind these actions can best be presented by quoting from a part of an informal report made by the Division Engineer, LMVD, early in June 1973:

> The MR&T Project has served admirably to protect the Valley from a major disaster in 1973. Even so, flooding of serious proportions has occurred throughout the Valley in areas where there is no authorized flood protection or where the authorized protection has not yet been constructed. Because of the heavy rains which accompany the buildup of a flood situation, there has also been considerable flooding from impounded waters in protected areas having gravity drainage outlets but no pumping plants. This is particularly true in the areas protected by the levees in the St. Louis District, the Tensas-Cocodrie levee in the Vicksburg District, and the Pointe Coupee levee in the New Orleans District.
>
> The scope of our flood fight emergency work was required not only by the sustained high stages throughout the system, including record stages on the Upper Mississippi, Illinois, and Atchafalaya Rivers, but by the potential which existed for even greater, catastrophic flooding. For over two months the main stem was perched extremely high, the ground soaked, and all the tributaries, reservoirs, and backwater storage areas were full. Under these conditions, additional rainfall in one or more of the major tributary basins, normally to be expected this time of the year, could have easily brought on increased flows approaching the project flood. The sole protection upon which the Valley depended was the MR&T Project, which is less than 50% complete. There was, however, no panic among the imperfectly protected people, because they had every confidence that the Federal project and the Corps would protect them.
>
> In a flood fight, time is precious, opportunities are fleeting, and unanticipated emergencies are unending. If something may have to be done, it must be done in advance of the time when the need is obvious. My decision was to prepare for a major flood fight. Under these circumstances, it was essential, as the awesome nature of the flood became clear, to get under way a massive program of emergency construction to preserve the integrity of our flood control works and to give us a fighting chance to save the Valley. We could have proceeded less aggressively than we did, doing no more than was immediately necessary, and trying piecemeal, to keep ahead of predicted stages. The probability of failure of such a 'brinkmanship' policy was too great. We prepared our floodways. We raised deficient levees and floodwalls. We established continuous contact with the media to keep a free flow of information to the people of the Valley. Setbacks, wave wash, 'potato ridges,' mud boxes, sheet pile, etc. became the

language of the day. As the rain continued, and interior flooding became serious, it became necessary to initiate extensive pumping operations in protected areas which have no pumping plants.

Raising the levees to a grade that would give us a fighting chance to pass the project flood was an important, urgent task. Our initial efforts in this regard were given a serious setback after they were well under way when it developed that the 1973 flood flow line was several feet higher than the flow line on which the levee grades were based. We had to further raise levees we had raised earlier in our emergency program. Many additional miles of levees which were supposedly up to design grade were found to be several feet too low. The emergency program of raising low levees to grade in minimum time has been a major undertaking, and required outstanding performance on the part of our personnel and our contractors. In the Atchafalaya Basin the levees were raised by earth works (potato ridges) where foundation conditions would permit, and by using sheet piling where foundations would not support additional earth. Where necessary to avoid unusually high 'potato ridges,' mud boxes were used. The concrete floodwalls at both Morgan City and Berwick, La., were topped with mud boxes. On the main stem levees, 'potato ridge' earth works and mud boxes have both been used. Because of the urgency, in the rapidly worsening flood situation, and to protect the levees from hauling truck traffic, the dirt was obtained by borrowing from the landside slope of the existing levee. Where the levee section was too small for this procedure, material had to be hauled from borrow pits. It was, of course, also necessary to raise the gates and the approaches to many of our structures, particularly in the Atchafalaya Basin.

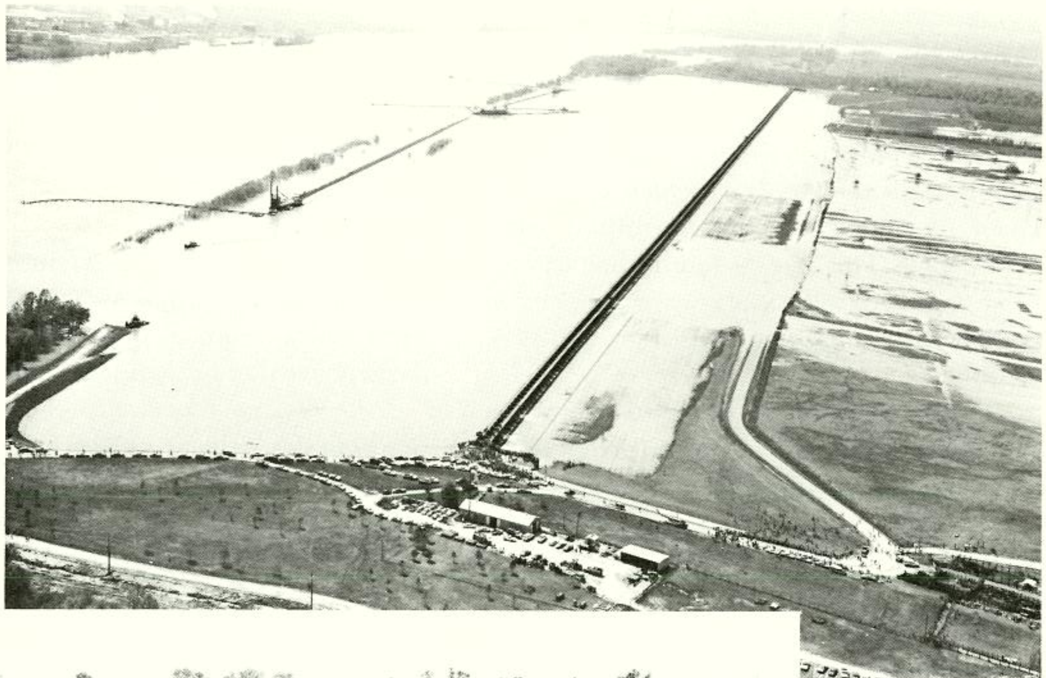
Perhaps our greatest concern during the flood has been the integrity of the Old River Low-Sill Structure. The south training wall on the Mississippi River side of the structure failed very early in the flood, causing violent eddy patterns and extreme turbulence. The toppled training wall monoliths worsened the situation. The integrity of the structure at this point was greatly in doubt. It was frightening to stand above the gate bays and experience the punishing vibrations caused by the violently turbulent, massive flood waters. We commenced the construction of a rock dike at the south end of the structure to dampen the eddy pattern, to realign the entrance flows, and to protect the structure and adjacent levee from being undermined. We opened Overbank and Morganza to lower the differential head through the Low-Sill Structure and to reduce velocities. As velocities were lowered, we were able to take bottom profiles in the forebay area. A scour hole about 150 feet wide and 50 feet deep was ultimately found immediately in front of the south half of the structure. This hole extended below the sheet pile cutoff wall and into the supporting piles, threatening to undermine the structure. To date we have placed some 118,000 tons of rock adjacent to and in the scour hole and are now making good headway toward correcting the situation, at least temporarily. As you can imagine, it was very difficult to work floating plant safely in front of the structure with the existing turbulence and high velocities. Remedial work would have been facilitated by closure of some or all of the structure gates, but this could not be done safely because of the basic design of the structure plus its weakened condition. Conditions were improved significantly by the construction of the rock dike at the south end of the structure and the use of the Overbank Structure and the Morganza Floodway. With the reduction of the differential head through the structure, we have been able to place our floating plant in position where we are getting excellent results with our rock placement.

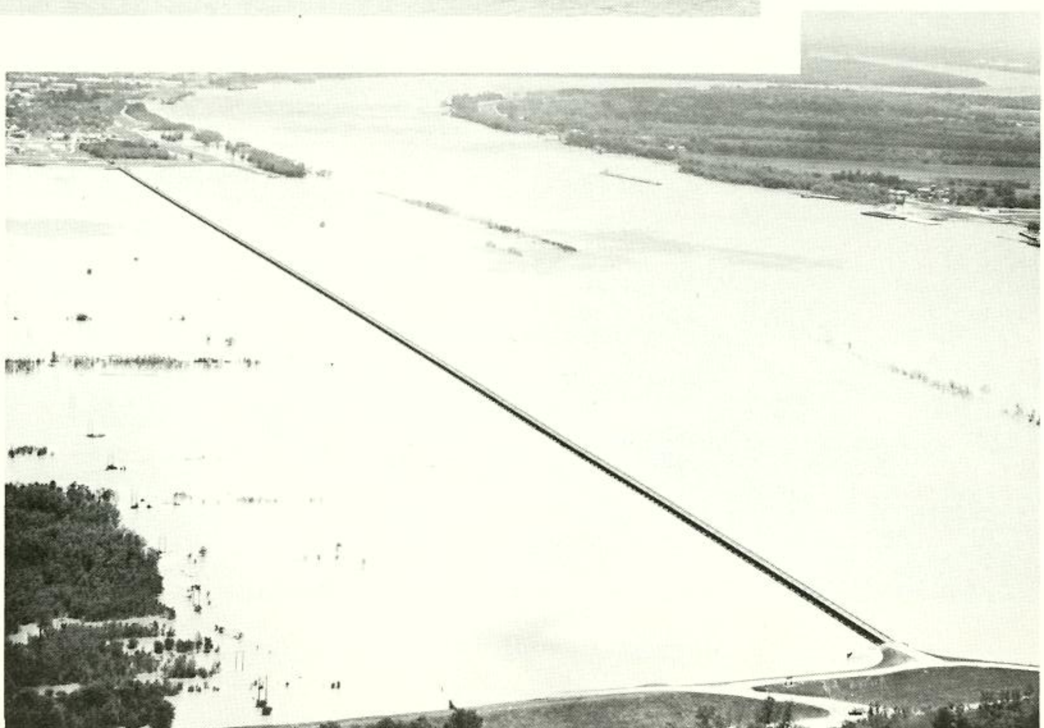
Some other Corps emergency activities on the Lower Mississippi were as follows:

Birds Point-New Madrid Floodway—Mobilization of Corps flood-fight forces was initiated north of Memphis on 16 March 1973. The Birds Point-New Madrid Floodway sector was a prime area of concern. On 22 March, the decision was made to raise the elevation of the upper fuseplug reach of the frontline levee to withstand an elevation equivalent to 60 feet on the Cairo gage. This required raising the levee approximately 2 feet for 11 miles. Within 46 hours after construction began, the 11 miles of levee had been raised to grade. Fortunately, the river crested at 55.7 feet at Cairo and operation of the floodway was not necessary.

Bonnet Carré Spillway—Bonnet Carré Spillway is located 25 miles above New Orleans, Louisiana, and is designed to convey 250,000 cfs from the Mississippi River to the Gulf via Lake Pontchartrain. Early in February, dredging to remove routine siltation was begun in the forebay area preparing for the possible future use of the spillway. A second dredge began work on 18 March, and on 3 April the third dredge began degrading the sedimentation levee in front of the structure. The spillway opening began on 8 April and continued until all 350 bays were opened on

BONNET CARRÉ SPILLWAY OPENING





11 April. Operation was successful in preventing excessive flows past New Orleans. The maximum diversion of flow through the spillway was 195,000 cfs. The spillway remained fully open until 31 May 1973, when it was closed in conjunction with the closing of the Morganza Floodway Structure at a rate which would not increase the stage on the Carrollton (New Orleans) gage. This was the fourth time that the spillway had been used since it was constructed in 1931, having been previously used in 1937, 1945, and 1950.

Morganza Control Structure—On 16 March 1973, Corps of Engineers forces, using Corps equipment, began to degrade the "potato ridge" levee in the forebay area of the Morganza Structure. On 15 April, because of a serious situation which had developed at the Old River Low-Sill Control Structure, final preparations were made to open the Morganza Floodway. The opening on April 17 had been coordinated with appropriate Federal, State, and local agencies. This was the first time Morganza had been used, and the opening was witnessed by a large crowd of spectators, including the Governor of the State of Louisiana.

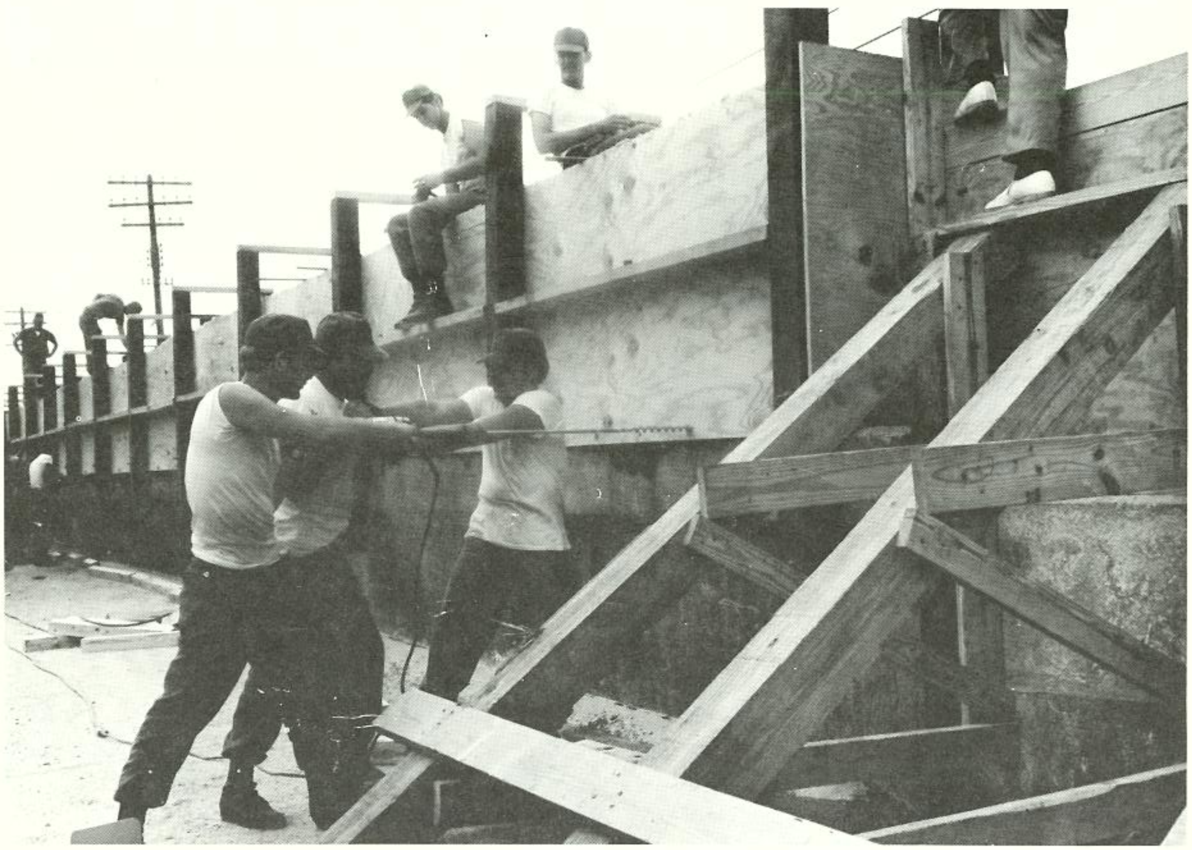
Atchafalaya River Basin

Phase II Corps of Engineers emergency activities began in the Atchafalaya Basin on 2 April 1973, although preliminary activities had been under way for over a month.

Levees and Floodwalls—Since many of the levees in the Atchafalaya Basin were below grade, some levee raising commenced early in the flood. Later, the U. S. Army Engineer Waterways Experiment Station (WES) performed a model study to evaluate the flood flow line. The model study showed that the water level in the lower Atchafalaya Basin would be higher than the

Morganza Control Structure during operation

Steel sheet piling used north of Morgan City, Louisiana, East Atchafalaya Basin protection levee



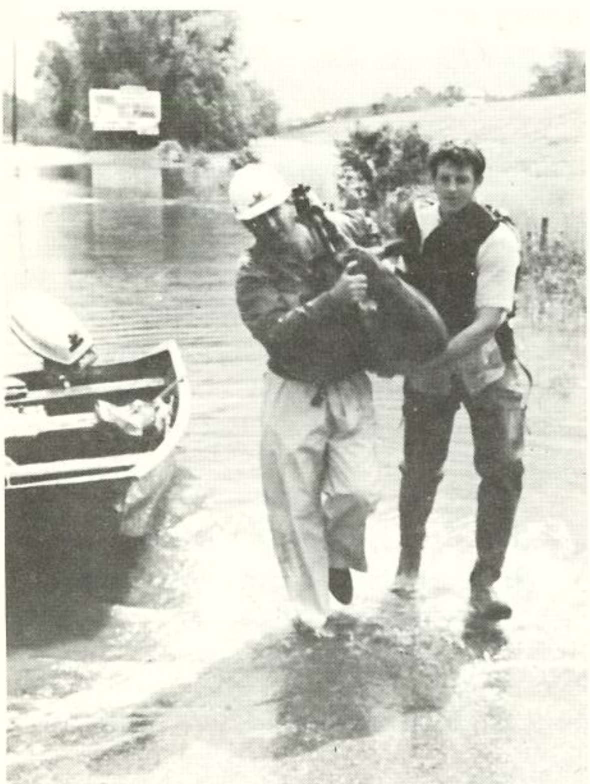
Construction of mudboxes atop floodwall at Morgan City, Louisiana, by U. S. 5th Army, 62d Engineer Battalion, Fort Hood, Texas

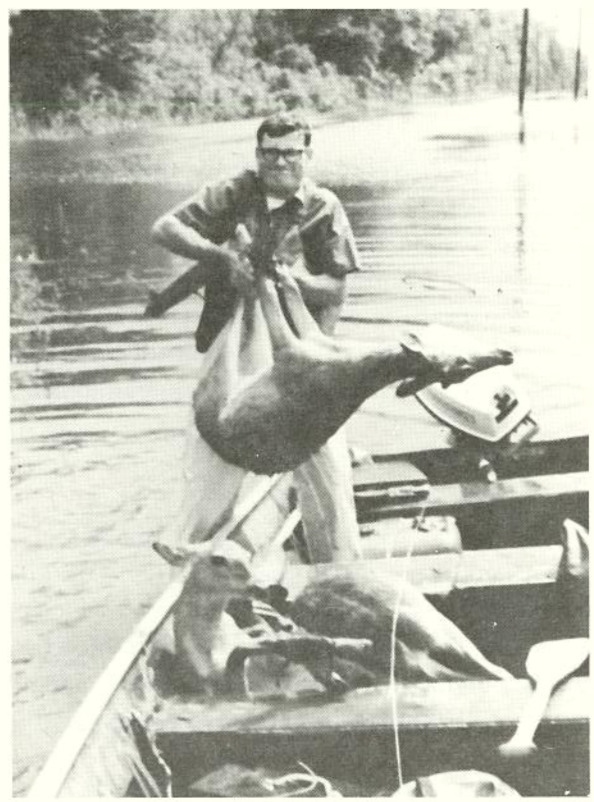
Mudboxes atop floodwall

Atchafalaya River at Morgan City, Louisiana

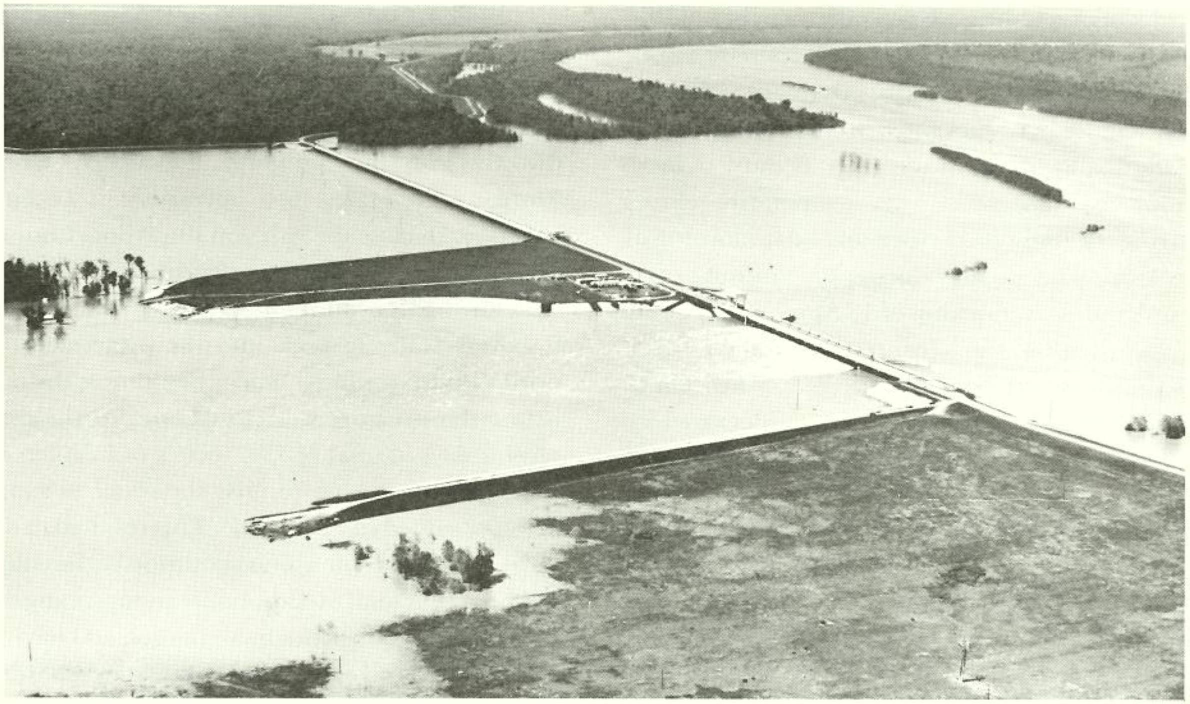
project flood flow line which was developed in 1963. With the new flow-line information, the predicted flood flows, and the possibility of a project flood imminent, Corps officials ordered additional raising of the lower Atchafalaya Basin levees and floodwalls to provide the required freeboard elevations. The flow line established from the hydraulic model and computer analysis was used as a basis for determining the required elevations and to locate the deficient levee sections. Floodwalls at Morgan City and Berwick, Louisiana, were determined to be deficient and were raised by installing mudboxes. Deficient levees in and around these cities were raised by using sandbags, earth fill, steel sheet piling, and mudboxes. Most of this work was performed by contract, starting on 11 April 1973; however, a large portion of the work in and around Morgan City and Berwick was performed by the 62d Engineer Construction Battalion of the Fifth U. S. Army, Fort Hood, Texas, which was mobilized specifically for this mission.

Morganza Floodway—On 5 March 1973, notices were mailed to people living in or having an interest in the Morganza Floodway, West Atchafalaya Floodway, Atchafalaya Basin Floodway, and the Bayou des Glaises Loop. The notice is an annual reminder to the interested parties that they are living or operating a business in the floodway. On 21 March 1973, the Corps sent telegrams to all persons having an interest in the Morganza forebay area, advising them to remove all livestock, fences, and equipment within 5 days after receipt of the notice. By 27 March all fences and livestock had been removed from the forebay. Two days later, on 29 March, water began overtopping the degraded forebay levee. On 17 April, with a large crowd watching, 42 of the 125

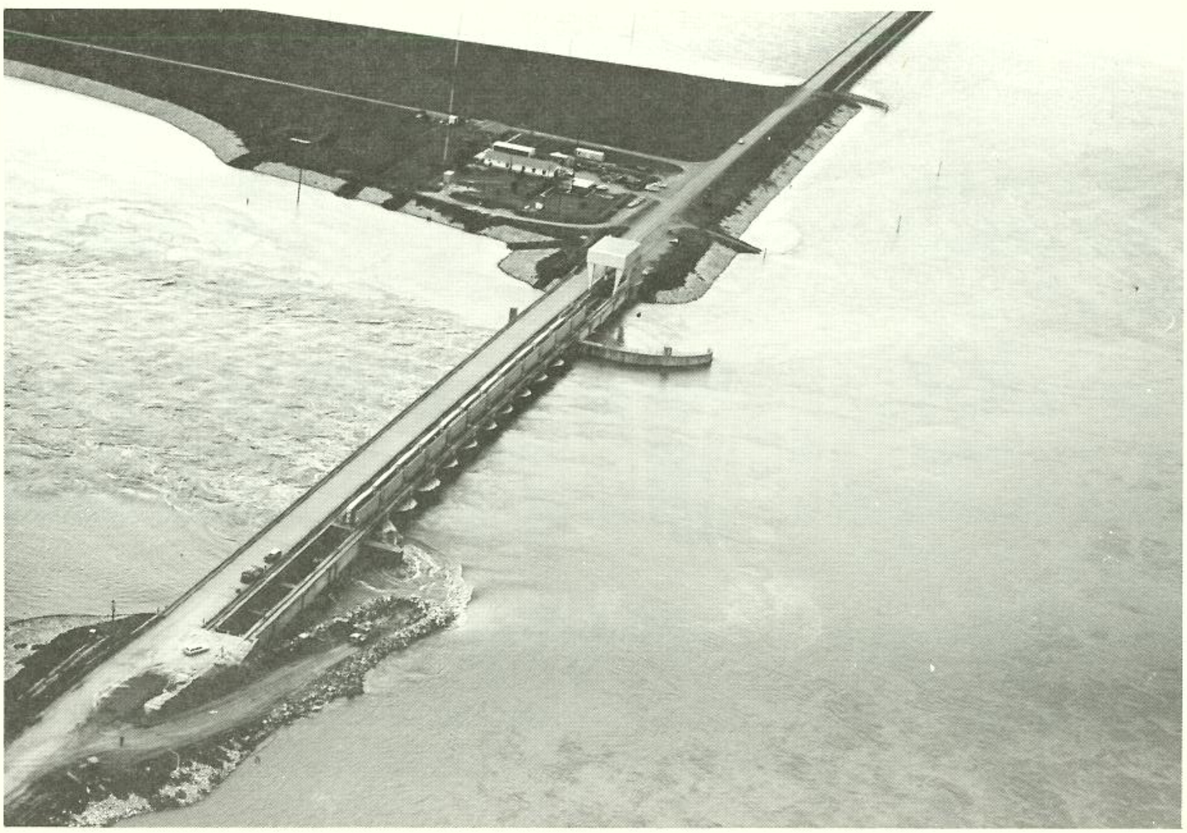




Wildlife rescue operations

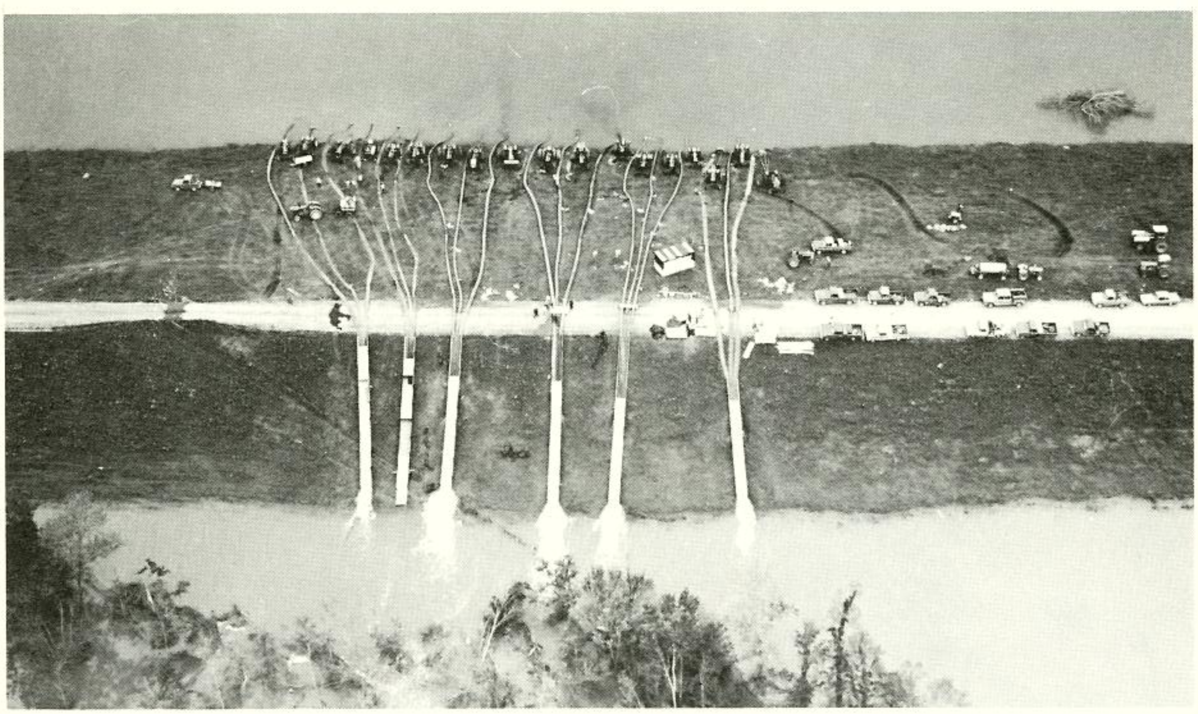


Overbank and Low-Sill Control Structures



Emergency repairs, rock dike at failed wing wall, Low-Sill Control Structure bays of the Morganza Control Structure were opened. The onrush of water exposed several problems, including adverse effects on the wildlife which did not have time to retreat from the rising waters. The Pointe Coupee Drainage Structure was temporarily prevented from closing by the malfunction of one of the gates. Because of these problems, Morganza was temporarily closed during the night of 17 April and early morning of 18 April. Then again, during the morning of 18 April and early morning of 19 April, 42 bays were reopened after the closure of Pointe Coupee Drainage Structure had been accomplished. On 19 April, 32 bays were again closed in order to reduce adverse effects on wildlife in the Morganza Floodway. Ten bays remained open. On 13 May the opening of additional bays of the control structures was begun to reduce the effect of rising Mississippi River stages on the damaged Old River Low-Sill Control Structure. Two bays per day were opened until a total of 20 bays were opened on 17 May. Operation of the structure continued as required until 2 June when closing commenced. It was completed on 3 July when all the water in the forebay had been drained.

Pointe Coupee Loop—The Pointe Coupee Loop area contains 80,000 acres of farmland. The area is completely encircled by levees and contains a single gravity drain structure, which empties directly into the Morganza Floodway. When Morganza was put into operation, it became necessary to close the gates on the Pointe Coupee Structure. A temporary malfunction of the structure gates allowed a small amount of floodway water to back into the protected area until closure could be made. Beginning the day before the structure was closed and for the next several days, a total of 13.6 inches of rain fell in this area threatening to raise the water in sump above the flood easement line. This resulted in the most spectacular pumping operation of the entire 1973 flood. A total of 41 portable pumps, ranging in size from 10- to 60-inch discharges, and having a total rated capacity of approximately 1400 cfs, were used. Pumping was begun on 18 April and completed on 15 June.

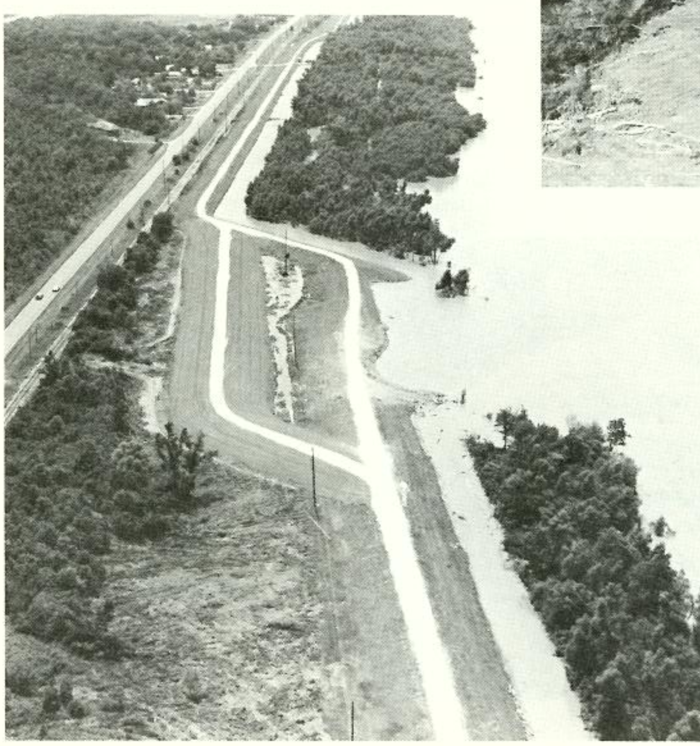


Pointe Coupee Loop pumping operations

BANK FAILURE EMERGENCIES

Bank failures, of whatever nature, that jeopardize protective levees are always a threat during floods. Major bank failures occurred in the Lower Mississippi Valley during the 1973 flood at four locations. The immediate remedy for a levee-threatening bank failure is to arrest the bank recession with stone or any other available material and construct a setback levee. There were four setback levees constructed during the flood emergency in the Lower Mississippi Valley. The northernmost one was at Pointe Pleasant, mile 205; the others were located at miles 130, 86, and 35 on the Mississippi River above Head of Passes, Louisiana. Three additional setback levees were required as a result of bank failures after the flood water receded.

Bank failure and construction of levee setback, mile 35 AHP, Mississippi River levee, vicinity of Nairn, Louisiana



Nairn levee setback completed, right descending bank of the Mississippi River

FLOOD-FIGHTING TECHNIQUES

The 1973 flood fight utilized a combination of old and new methods of flood fighting. The sandbag was still prevalent in all flood-fight areas, but many new methods were introduced to aid the sandbag operation. Polyethylene film was used extensively, sometimes as liners for a sandbag levee to provide watertight protection, and sometimes as wave-wash protection measures. Mudboxes and flashboards were used to raise miles of levee, and they were sometimes prefabricated in panels and assembled on the site. Portable, wheel-mounted pumps powered by farm tractors, were in great demand during the entire flood-fight operation. Their use protected many communities from seepage and interior drainage accumulations. The vast expanse of the 1973 flood provided an excellent opportunity to test the use of modern construction equipment for such items as levee raising and degrading operations. Stone protection was used in quantities never before attempted in a flood fight through mechanized means. Seepage through levees and sand boils which appeared land side of the levees were old problems encountered again in 1973 throughout the entire flood area. The most common method of combatting seepage erosion of levee slopes is to excavate lateral drains to collect the water and lead it away from the affected area. Sand boils are normally ringed either by sandbags or in some cases by metal drums or other means to provide a ring around the boil, and thus create a head to reduce the flow of water so that it carries no material. If the flow of water is not carrying material, a boil normally requires no protective measures. If a boil is ringed to create a head, the head should not be excessive, and no attempt is made to completely stop the flow of water because it will break out elsewhere. Wave wash on the river side of the levees is a common problem during flooding. The wave action at the waterline tends to scour and erode into the levee section. One of the most common methods of combatting wave wash is by placing sandbags at the waterline. This is not always satisfactory, because the wave action, if violent enough, will remove the sand from burlap bags. The newer style close-woven plastic bags were found to perform better as wave-wash protection than traditional burlap or open-mesh plastic bags. Another method of protecting against wave wash

Typical example of a sand boil, ringed with sandbags to create enough head to slow the flow is to construct a mattress or a fence at the waterline. Snow fencing can be laid at the waterline, anchored down by sandbags or other means, and will effectively break up wave action. Nylon-reinforced polyethylene sheeting proved vastly superior to the more common 6-mil variety. The procedure of using bulldozers to push material from the land-side slope of levees to the crown to prevent overtopping resulted in saving several levees in the Mississippi River Basin. Tracks left on the land side by the equipment were prone to collect seepage water which initially resulted in a serious problem. This was solved by dragging with a heavy rail to smooth the surface.

ACTIVITIES OF STATE AGENCIES, LOCAL INTERESTS, AND INDIVIDUALS

The primary local interests with which the Corps dealt were the local levee and drainage district boards and city administrations. Many of these officials had been associated with flood protection activities for years and were very proficient in their emergency work. Some of the larger and less affected levee boards were able to conduct the flood-fight activities without appreciable assistance from Corps personnel. Others required large-scale Corps support from the beginning of the emergency. The small drainage districts were, for the most part, pressed to the limits of their resources.

State and local police agencies, state highway departments, county highway departments, state Civil Defense officials, and others were active in all flooded areas. Civil Defense officials, acting at least in part on information supplied by the Corps, evacuated flood areas and performed essential services as liaison centers for flood-fight efforts. Volunteer labor from high schools and colleges were extremely helpful. Appropriate governors, members of Congressional delegations, and other interested state and national officials were informed prior to major actions.

ACTIVITIES OF MILITARY UNITS

U. S. COAST GUARD

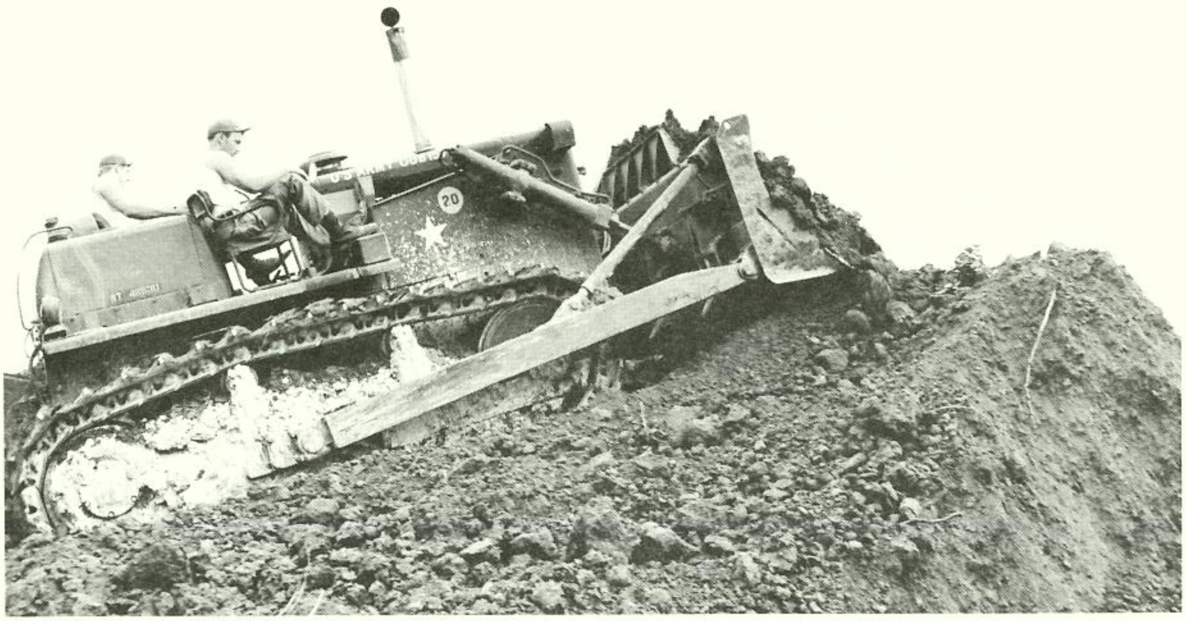
Coast Guard personnel were active in many areas during the flooding. They performed services such as evacuation, rescue, transportation of material and personnel, and control of waterborne traffic and were very helpful during the emergency.

NATIONAL GUARD

National Guard troops were made available by every state involved in significant flood-fight activities. National Guard personnel were utilized in many ways during the emergency. They provided protection against looting, helped with levee maintenance, assisted in evacuation, and rendered many meaningful services.

FIFTH U. S. ARMY 62d ENGINEER BATTALION

With a critical flood situation threatening the Morgan City, St. Mary Parish, Louisiana, area, the Division Engineer, LMVD, through the Office of the Chief of Engineers, Washington, D. C., on 19 April 1973, requested that the 62d Engineer Battalion, Fort Hood, Texas, be committed in the



Bulldozers operated by 62d Engineer Battalion were effective in levee-raising operations, Morgan City, Louisiana

Morgan City area under PL 84-99.

The 62d Engineer Battalion arrived at Morgan City on 22 April 1973 and rendered outstanding flood-fighting assistance until 12 May 1973. During this period the battalion surveyed approximately 38.5 miles of levee cross section, hauled and placed 6430 cubic yards of shell on levee roads, constructed 2.76 miles of flashboard protection on the Morgan City back levee, and also constructed mudboxes atop floodwalls at various locations.

PUBLIC AFFAIRS SUMMARY

Early in March 1973, when it appeared that a major flood might be imminent, the basic public affairs plan, based on existing regulations and amplified to meet expanded services, was placed into effect. Various points of contact for local and national news media were established.

Public Affairs Officers generally received a daily briefing in the Emergency Operations Centers. At many of these briefings, local and national news media were in attendance. Coverage by all the networks, including the British Broadcasting Company, and the national press was significant, increasing in proportion to the progress of the flood.

Assistance to the press was well received, and a personal working relationship was in effect throughout the period. City, county, and state officials were kept informed of newsworthy items as they occurred.

Public meetings were held at various times at specific locations to inform interested populace of the water stages and the effects it would have on their property. This enabled them to plan for any emergency.

The responses of both the public and the news media were very favorable to the public affairs effort and that of the Corps expended during the flood of 1973.

Section V

AREAS FLOODED, FLOOD DAMAGES, AND FLOOD DAMAGES PREVENTED

In the drainage basin of the Mississippi River, 16,711,500 acres were flooded. Areas flooded with and without projects are listed by basins for urban, cleared, wooded, and other areas, and are summarized by basins in Table 9 and by states in Table 10. Plate 12 shows areas flooded in the Lower Mississippi Valley with and without the Federal flood control project.

Flood damages with and without projects amounted to $1,154,770,000 and $15,585,300,000, respectively, resulting in flood damage prevented in the amount of $14,430,530,000. These damages and damages prevented are summarized by basins in Table 11 and by states in Table 12.

During the flooding, navigation continued to move on the Mississippi River but with some delays and at a higher operating cost.

TABLE 9

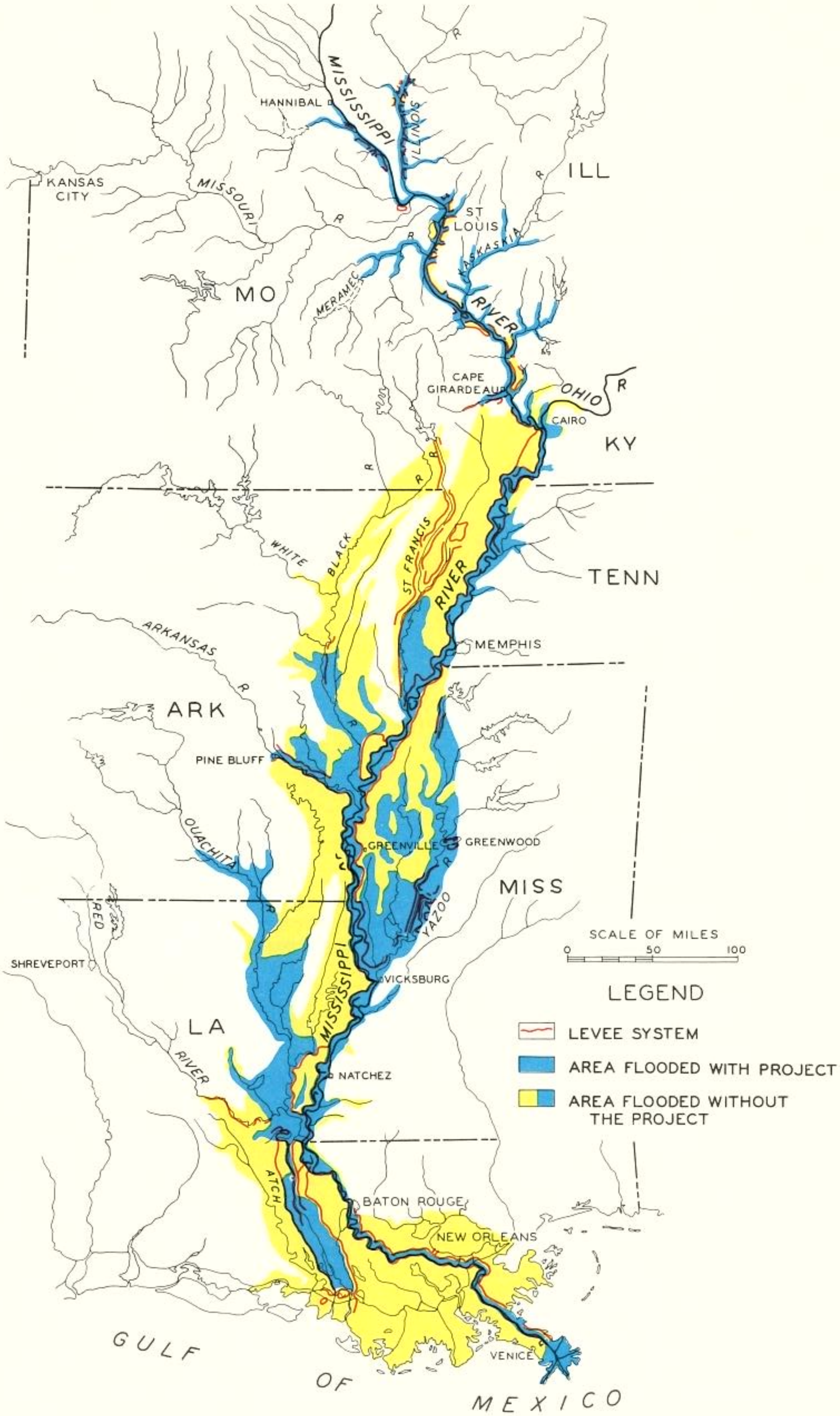
SUMMARY OF AREAS INUNDATED BY BASINS, 1973 FLOOD

Basin	Acres Flooded With Projects				Acres Flooded Without Projects			
	Urban	Cleared	Wooded	Other	Urban	Cleared	Wooded	Other
Upper Mississippi River	6,600	845,800	113,600	25,800	19,000	1,280,100	161,925	90,420
Missouri River	5,200	542,510	5,420	117,470	7,980	690,300	6,900	149,690
Illinois River	185	145,904	3,499	2,400	1,960	407,437	4,400	5,100
Ohio River	2,350	727,000	204,900	0	3,500	964,100	269,600	0
Arkansas River	8,740	499,210	408,500	62,600	27,460	1,378,280	610,720	174,040
St. Francis River	50	153,500	253,605	0	5,050	2,536,500	4,327,545	0
White River	0	269,000	899,180	11,900	120	491,900	955,400	24,500
Ouachita River	330	829,450	1,476,970	0	23,400	2,779,280	1,847,450	0
Red River	3,010	248,480	953,750	22,800	12,000	383,000	1,411,400	64,250
Yazoo River	1,730	1,169,130	540,490	0	27,730	2,845,420	1,279,220	0
Big Black River and SW Tributaries	140	59,860	152,310	0	140	62,150	206,680	0
Main Stem-Mississippi River	1,600	353,830	1,186,230	0	2,900	353,830	1,186,230	0
Atchafalaya River	500	24,000	707,000	54,000	31,000	70,000	898,000	54,000
Pontchartrain Lake	1,550	20,000	465,000	466,000	117,000	112,000	605,000	678,000
Mississippi-Atchafalaya Area	2,300	58,000	751,000	1,210,000	114,000	494,000	875,000	1,595,000
Cocodrie-Boeuf-Teche-Vermilion	200	134,000	304,000	199,000	33,000	311,000	489,000	213,000
Total	34,495	6,079,674	8,425,454	2,171,970	426,240	15,159,297	15,134,470	3,048,000

TABLE 10

SUMMARY OF AREAS INUNDATED BY STATES, 1973 FLOOD

State	Acres Flooded With Projects				Acres Flooded Without Projects			
	Urban	Cleared	Wooded	Other	Urban	Cleared	Wooded	Other
Arkansas	950	934,365	2,611,515	28,130	16,250	3,655,725	6,535,305	57,740
Illinois	3,035	608,104	67,699	9,100	16,110	1,259,037	97,100	20,620
Indiana	200	194,700	48,000	0	400	272,400	68,000	0
Iowa	600	65,250	10,400	9,200	800	177,150	44,535	68,090
Kansas	2,390	181,200	22,670	33,140	9,350	446,670	83,500	91,050
Kentucky	400	177,340	60,500	0	800	211,440	69,500	0
Louisiana	7,320	934,770	3,595,160	1,929,000	315,490	3,360,130	4,523,420	2,540,000
Mississippi	2,460	1,338,260	1,148,910	0	28,460	3,016,840	1,942,010	0
Missouri	8,050	982,375	248,800	113,110	12,180	1,513,175	733,080	127,840
Ohio	1,500	900	200	0	1,700	1,300	300	0
Oklahoma	7,190	286,330	86,880	38,600	20,140	799,100	251,420	108,440
Tennessee	250	272,400	198,900	0	400	331,200	218,500	0
Texas	50	59,530	325,420	11,590	4,050	100,980	567,400	34,370
Wisconsin	100	14,150	200	100	100	14,150	200	100
Total	34,495	6,079,674	8,425,454	2,171,970	426,240	15,159,297	15,134,470	3,048,000



FLOOD OF 1973

LOWER MISSISSIPPI VALLEY

PLATE 12

TABLE 11

SUMMARY OF 1973 FLOOD DAMAGE AND DAMAGES PREVENTED BY BASINS

Basin	Damages With Existing Projects ($)	Damages Without Projects ($)	Damages Prevented by Projects ($)
Upper Mississippi River	342,257,000	1,469,848,000	1,127,591,000
Missouri River	30,903,000	135,500,000	104,903,000
Illinois River	12,463,000	71,040,000	58,577,000
Ohio River	30,749,000	95,953,000	65,204,000
Arkansas River	15,635,000	155,791,000	140,156,000
St. Francis River	52,980,000	734,589,000	681,909,000
White River	47,487,000	75,870,000	28,383,000
Ouachita River	90,005,000	2,586,586,000	2,496,581,000
Red River	25,742,000	35,062,000	9,319,000
Yazoo River	169,452,000	2,005,854,000	1,836,402,000
Big Black River and SW Tributaries	5,646,000	6,320,000	674,000
Main Stem-Mississippi River	239,679,000	104,519,000	-135,159,000[a]
Atchafalaya River	60,547,000	105,752,000	45,205,000
Pontchartrain Lake	7,129,000	6,118,760,000	6,111,631,000
Mississippi-Atchafalaya Area	18,300,000	1,818,698,000	1,800,398,000
Cocodrie-Boeuf-Teche-Vermilion	5,794,000	120,352,000	114,558,000
Total	1,154,770,000	15,640,493,000	14,485,723,000

[a] This basin includes the unprotected areas between the levees or between the levee and the opposite bank hills, where greater damages were sustained with the project than without the project due to increased river stages resulting from confinement of flows.

TABLE 12

SUMMARY OF 1973 FLOOD DAMAGES AND DAMAGES PREVENTED BY STATES

State	Basin	Damages With Existing Projects ($)	Damages Without Projects ($)	Damages Prevented by Projects ($)
Arkansas	Arkansas River	6,710,000	98,554,000	91,844,000
	Main Stem-Mississippi River	21,301,000	18,677,000	-2,624,000[a]
	Ouachita River	15,902,000	428,651,000	412,749,000
	Red River	1,883,000	4,149,000	2,266,000
	St. Francis River	37,471,000	557,500,000	520,029,000
	White River	46,312,000	73,551,000	27,239,000
	Total	129,579,000	1,181,082,000	1,051,503,000
Iowa	Upper Mississippi River	12,724,000	83,139,000	70,415,000
	Missouri River	0	2,577,000	2,577,000
	Total	12,724,000	30,523,000	17,799,000
Illinois	Illinois River	12,463,000	71,040,000	58,577,000
	Upper Mississippi River	242,177,000	1,007,745,000	765,568,000
	Ohio River	3,473,000	11,909,000	8,436,000
	Main Stem-Mississippi River	68,000	8,068,000	8,000,000
	Total	258,181,000	1,098,762,000	840,581,000
Indiana	Ohio River	5,856,000	7,468,000	1,612,000
	Total	5,856,000	7,468,000	1,612,000
Kansas	Arkansas River	1,795,000	14,827,000	13,032,000
	Missouri River	2,382,000	24,390,000	22,008,000
	Total	4,177,000	39,217,000	35,040,000
Louisiana	Atchafalaya River	60,547,000	105,752,000	45,205,000
	Mississippi-Atchafalaya Area	18,300,000	1,818,698,000	1,800,398,000
	Cocodrie-Boeuf-Teche-Vermilion	5,794,000	120,352,000	114,558,000
	Ouachita River	74,103,000	2,157,935,000	2,083,832,000
	Main Stem-Mississippi River	146,257,000	6,433,000	-139,824,000[a]
	Red River	21,557,000	23,877,000	2,320,000
	Pontchartrain Lake	6,802,000	6,118,433,000	6,111,631,000
	Yazoo River	352,000	861,000	509,000
	Total	333,712,000	10,352,341,000	10,018,629,000
Minnesota	Upper Mississippi River	242,000	2,247,000	2,005,000
	Total	242,000	2,247,000	2,005,000
Missouri	Main Stem-Mississippi River	7,080,000	7,080,000	0
	Missouri River	28,521,000	108,533,000	80,012,000
	St. Francis River	15,509,000	177,089,000	161,580,000
	Upper Mississippi River	81,092,000	368,702,000	287,610,000
	White River	1,175,000	2,319,000	1,144,000
	Total	133,377,000	663,723,000	530,346,000
Kentucky	Ohio River	6,549,000	38,631,000	32,082,000
	Main Stem-Mississippi River	867,000	4,523,000	3,656,000
	Total	7,416,000	43,153,000	35,738,000

(Continued)

[a] This basin includes the unprotected areas between the levees or between the levee and the opposite bank hills, where greater damages were sustained with the project than without the project due to increased river stages resulting from confinement of flows.

TABLE 12 (Concluded)

State	Basin	Damages With Existing Projects ($)	Damages Without Projects ($)	Damages Prevented by Projects ($)
Mississippi	Big Black River and SW Tributaries	5,646,000	6,320,000	674,000
	Main Stem-Mississippi River	51,549,000	43,820,000	−7,729,000[a]
	Pontchartrain Lake	327,000	327,000	0
	Yazoo River	169,100,000	2,004,993,000	1,835,893,000
	Total	226,622,000	2,055,460,000	1,828,838,000
Ohio	Ohio River	8,317,000	15,780,000	7,463,000
	Total	8,317,000	15,780,000	7,463,000
Oklahoma	Arkansas River	7,130,000	42,410,000	35,280,000
	Red River	489,000	3,000,000	2,511,000
	Total	7,619,000	45,410,000	37,791,000
Tennessee	Main Stem-Mississippi River	12,557,000	15,918,000	3,361,000
	Ohio River	4,642,000	17,596,000	12,954,000
	Total	17,199,000	33,514,000	16,315,000
Texas	Red River	1,813,000	4,035,000	2,222,000
	Total	1,813,000	4,035,000	2,222,000
West Virginia	Ohio River	1,913,000	4,569,000	2,656,000
	Total	1,913,000	4,569,000	2,656,000
Wisconsin	Upper Mississippi River	6,023,000	8,015,000	1,992,000
	Total	6,023,000	8,015,000	1,992,000
	Total	1,154,770,000	15,640,493,000	14,485,723,000

[a] This basin includes the unprotected areas between the levees or between the levee and the opposite bank hills, where greater damages were sustained with the project than without the project due to increased river stages resulting from confinement of flows.

Section VI
COORDINATION WITH OTHER FEDERAL AGENCIES

GENERAL

Close coordination was maintained between Corps officials and several Federal agencies throughout the emergency. The principal agencies with which coordination was maintained and cooperative efforts were conducted are mentioned below.

FEDERAL DISASTER ASSISTANCE ADMINISTRATION

Disaster areas were established by presidential declaration in the states of the Mississippi River Basin that suffered major disaster damages. Under provisions of PL 606, 91st Congress, Executive Order 11575, and Title 32 Code of Federal Regulations, Parts 1709 and 1710, the Corps of Engineers is directed to provide assistance to the affected areas when requested by FDAA. This assistance consists of performing inspections and making survey reports showing estimates of costs for clearance of debris from public and private property, and for repairs to public owned and maintained dikes, levees, irrigation works, drainage facilities, etc., that are not eligible under PL 84-99 or other statutory authorities.

Upon receipt of a directive from FDAA, Corps inspectors were dispatched throughout the damage areas to perform surveys as required. The areas to be surveyed were:

- A Clearance of debris and wreckage;
- B Emergency protective measures;
- C Repair or replacement of streets, roads, and highway facilities;
- D Repair or replacement of dikes, levees, irrigation works, and drainage facilities;
- E Repair or replacement of public buildings and related equipment; and
- F Repair or restoration of publicly owned utilities.

Corps of Engineers facilities were required to allocate manpower to these surveys coincidental with efforts to repair damaged levees and other flood protection works. The Corps performed a total of 15,600 man-days work for FDAA.

U. S. WEATHER SERVICE

The Corps of Engineers maintained continuous contact with the U. S. Weather Service Bureau to obtain gage readings and stage and weather predictions. These predictions and forecasts were essential for planning the flood-fight operations on a day-to-day basis.

U. S. COAST GUARD

As stated previously, the Coast Guard actively participated and assisted in the overall flood emergency effort throughout the Mississippi River Basin. The Coast Guard performed many valuable services, such as evacuation, transportation of men and materials, emergency rescue operations, and, at Corps of Engineers request, monitored river traffic for excessive speeds to prevent wave-wash damage to levee systems. The Corps of Engineers kept the Coast Guard apprised of lock closings and openings. Excellent cooperation was maintained at all times.

Section VII

ANALYSIS, CONCLUSIONS, AND RECOMMENDATIONS OF THE MISSISSIPPI RIVER FLOOD PROTECTION SYSTEM

TRIBUTARY BASINS

The Federal protection system in the tributary basins proved sound and effective. Local and private works were less effective, with frequent failures. Many of these failures resulted from the levees or other structures being subjected to floodwaters greatly exceeding those they were designed to withstand. Reservoirs, levees, and other flood-control works in the tributary basins reduced local flooding and the reservoirs combined to lower the flood crest on the upper Mississippi River at St. Louis, Missouri, by 2 feet and the crest at Cairo, Illinois, on the lower Mississippi River by more than 4.5 feet. The areas flooded and the damages sustained strongly suggest that flood protection might be well justified in many additional areas.

MISSISSIPPI RIVER AND TRIBUTARIES PROJECT

GENERAL

An analysis of the MR&T Project based on the 1973 flood experience reveals many areas of concern of varying importance. By far the most important single item of concern, and the one demanding the most immediate attention was the channel deterioration which was found to have developed. This problem and others highlighted by the flood are discussed in the following subparagraphs.

CHANNEL DETERIORATION, PROJECT DESIGN FLOOD FLOW LINE AND LEVEE-RAISING

Design Basis

The MR&T Flood-Control Plan is designed to control the Project Design Flood of 3,030,000 cfs at the latitude of Old River. The project levees and floodwalls are designed to confine the project flood discharge based on a computed flow line. The project flow line and hence the project levee grade had been established based on stage-discharge relationships during the floods of 1945 and 1950, and the corresponding channel and overbank conditions. As the 1973 flood developed and preparations for a major flood continued, it became apparent that the stage-discharge relationship was several feet higher than the stage-discharge relationship upon which levee grades were based. Channel efficiency has diminished throughout the lower Mississippi River due to changes arising from the dynamic nature of the alluvial river, the persistent tendency of the river to meander, the instability introduced by the cutoff program, and a generally incomplete river stabilization program. These changes included the formation of meanders, divided flows, and sandbars, and have occurred generally throughout the middle reach of the lower river. In developing the original Project Design Flood Flow Line, the possibility of a decrease in channel efficiency was considered, but no special allowance was made for this loss. Faced with the prospect of a flood reaching project flood proportions, an examination of flow lines was conducted to determine the steps that would be necessary to protect the Valley.

Stage-Discharge Relationships

The Project Design Flood Flow Line had been established using data from the 1945 and 1950 floods. Stage-discharge measurements made during the 1973 flood showed that a serious reduction in channel capacity had taken place in the middle reach of the lower Mississippi River since 1950. At the peak stage of the 1973 flood, with the river approximately 10 feet above bank-full stage, observations indicated that the capacity of the river was about 15 percent (350,000 cfs) less than the capacity under 1950 channel conditions. At Vicksburg, this amounts to a shift of 4.7 feet with 1.5 feet attributable to loop effect (discussed later) and with the remaining 3.2 feet attributable to channel deterioration. A similar pattern of shifts was observed at other gaging stations along the middle reaches of the lower Mississippi River. The two main causes of these shifts, channel deterioration and loop effect, are discussed in subsequent paragraphs.

Channel Deterioration

To determine the effect of channel deterioration on the stage for the Project Design Flood discharge, it was necessary to develop a method to extrapolate from observed data to higher flows. Because of the unreliable nature of graphically extrapolated data, a computational method was utilized. The revised stage was computed by adjusting 1950 channel characteristics to reflect the changes in bank-full channel efficiency that were identified from the 1973 flood data with the overbank channel characteristics held constant. Overbank conditions had not changed since 1950 to any measurable extent; therefore, the shift which would occur at project flood levels would be caused by the channel deterioration within banks. For this reason, the net effect of the reduced channel capacity diminishes as stages rise above bank-full. Utilizing these revised channel characteristics, the increase in flow line attributable to channel deterioration was computed. This computational approach was verified on the Mississippi Basin Model at Clinton, Mississippi. The increase of 4.5 feet in stage at Vicksburg observed at bank-full capacity translates by computational methods to be 2.8 feet at project flood level. The increase in project flood stage resulting from channel deterioration at other locations amounts to 1.6 feet at Arkansas City, 2.3 feet at Natchez, and 2.3 feet at Red River Landing. These resulting stages were then increased by an allowance to account for the loop-effect as described in the next paragraph.

Loop-Effect

Some increase in stage during the 1973 flood was attributable to the loop-effect observed in stage-discharge relationships. It is a phenomenon of river flow hydraulics that a rising river will pass a given discharge at a lower stage than a falling river. When the recession of the first flood peak is followed with a secondary rise before the loop has closed back onto itself, the new rising rating curve is stepped upward producing higher stages for a given discharge. Some floods, like those in 1937 and 1950, had a fairly smooth rise and fall. In contrast, the 1973 flood was a long flood, in which high stages were sustained over a period of months, with successive crests, partial falls, followed by rises to new crests. This greatly compounded the loop-effect. The 1973 flood clearly demonstrated that the Project Design Flood could occur as a result of a succession of moderate to large storms, which would produce a stage-discharge loop curve similar to the 1973 flood. This important effect had not been adequately provided for in previous project flood flow-line determinations. In the interest of economy of levee construction, an average rating curve had been used in establishing the Project Design Flood Flow Line. It is now evident, in a valley such as the Mississippi where the consequences of levee overtopping are unacceptable, that the use of an average rating curve is unacceptable. Protection must be based on the most severe case reasonably expected to occur. In correcting this situation, other Mississippi River floods exhibiting a multiple loop-effect were analyzed to arrive at a reasonable value to add to the Project Design Flood Flow Line, as corrected for channel deterioration. As a result, at the project flood discharge, the following stage increases for loop-effect were added to the stage increases for channel deterioration: 2.4 feet at Arkansas City, 1.7 feet at Vicksburg, 1.7 feet at Natchez, 1.7 feet at Red River Landing, and 1.0 foot at Baton Rouge.

Future Channel Deterioration

Previous flow-line calculations had considered that the channel in the middle reach would attain equilibrium under conditions existing in the 1945-50 period. This assumption has proven to be erroneous. The rate at which the channel stabilization program was pursued did not keep pace with river developments, with the result that some of the gains of the cutoff program of the thirties were lost. Some deterioration or loss in flow capacity has occurred continuously since 1950. The high flows experienced in 1973 permitted the quantitative evaluation of the degree of deterioration in channel capacity associated with large floods. As channel stabilization works are currently estimated to be 58 percent complete within the middle reach, some additional deterioration can be expected before the program of stabilization is complete, and an allowance for this deterioration must be included in the adjusted flow line. The following were selected as reasonable allowances in the project flood flow line to account for this factor: 0.5 foot at Arkansas City, 1.0 foot at Vicksburg, and 0.5 foot at Natchez.

Summary of Mississippi River Adjusted Flow Line

Because of the loss of channel capacity to date and the need to protect against such factors as loop-effect and a minimum level of future deterioration, the project flood flow line and corresponding levee heights will require substantial raising in the middle reach of the lower Mississippi River. A comparison of the 1973 Adjusted and the original Project Design Flood Flow Lines for key stations on the lower Mississippi River is given in Table 13.

Atchafalaya Basin Floodway Adjusted Flow Line

The situation in the Atchafalaya Floodway somewhat parallels that in the Mississippi. The floodway is bounded by the East and West Guide Levees to contain flood flows passed down the Atchafalaya Basin. The required discharge through the Atchafalaya Floodway during design flood conditions for the MR&T Project is 1,500,000 cfs. Guide levees in conjunction with a central channel through the floodway are designed to confine this design flood. Without such floodway capacity in the Atchafalaya, the means for handling floods approaching project dimensions in the Lower Mississippi Valley are incomplete, and the extensive industrial and urban developments below the latitude of Old River outside the floodway, such as the Baton Rouge-New Orleans complex, are in jeopardy.

Early in the 1973 flood, observed stage-discharge data verified by hydraulic model studies on the Mississippi Basin Model at Clinton, Mississippi, showed that under existing conditions the discharge that could safely be passed through the Atchafalaya Basin Floodway was approximately 800,000 cfs. Extremely heavy sedimentation has been actively occurring in the lower end of the floodway from Six Mile Lake to Morgan City and in the Atchafalaya Bay, resulting in unusually high stages at Morgan

TABLE 13

ORIGINAL AND ADJUSTED FLOW LINES

Location	Original Flow Line feet	'73 Adjusted Flow Line feet	Change feet
Mhoon Landing, Arkansas	213.3	213.3	0
Helena, Arkansas	204.3	204.8	+0.5
Arkansas City, Arkansas	154.1	158.6	+4.5
Vicksburg, Mississippi	105.4	110.9	+5.5
Natchez, Mississippi	80.0	84.5	+4.5
Red River Landing, Louisiana	61.0	65.0	+4.0
Baton Rouge, Louisiana	46.4	47.4	+1.0
Donaldsonville, Louisiana	33.6	33.6	0

City. Studies are under way to determine measures that will relieve this situation. Substantial data on current Atchafalaya Basin flow characteristics were obtained during the 1973 flood, permitting a reevaluation of the project flood flow line. This reevaluation was verified in the model using the 1973 flood stage-discharge observations, and model runs were made for the project flood conditions. Based on these model runs, the project flood flow line was adjusted 2 to 4 feet, depending on location.

Impact of Adjusted Flow Line

Before the 1973 flood the majority of the levees along the main stem of the Mississippi had been raised to the project design grade, but in the Atchafalaya Basin most of the levees were substantially below the project design grade. This levee work was included in the project cost estimate and was scheduled to be completed as funds became available. The 1973 Adjusted Project Flood Flow Line requires an extensive increase in the amount of levee work required to protect against the project flood. Approximately 800 miles of levees along the Mississippi River, in the tributary areas, and in the Atchafalaya Basin Floodway will have to be raised in varying amounts in the affected reaches to provide this protection.

Alternative Solutions

To protect the integrity of the levee system, considering the adjusted flow line, a number of alternative solutions were examined, all of which have been studied in some detail. It was considered essential that the selected solution be immediately pursuable, adequate to provide security to the Valley, and accomplishable within a reasonable time frame and at a reasonable cost. The alternatives included raising levees, storing excess floodwaters in additional reservoirs, increasing the hydraulic capacity of the river by dredging and cutoffs, diverting flood flows, and widening floodways. The principal alternative solutions are:

- Storing excess floodwaters in additional reservoirs
- Increasing the hydraulic capacity of the river by dredging and cutoffs
- Diverting flood flows
- Widening existing floodways

A general description of each alternative and its order-of-magnitude estimated cost are discussed below.

Alternatives Considered

Storing Excess Floodwater in Additional Reservoirs—Consideration was given to lowering the flow line by providing additional reservoirs with a combined storage capacity sufficient to reduce stages as necessary to conform to the original Project Design Flood Flow Line. Lowering the discharge to stay within the 1973 Adjusted Project Design Flood Flow Line would require 27 million acre-feet of flood-control storage. For one combination of storms, a total of 69 reservoirs would be required to provide the required storage. Fifty-six of these could be headwater reservoirs in the Ohio, Upper Mississippi, and Missouri River Basins. One could be a main stem reservoir about 7 miles upstream of Cape Girardeau, Missouri. Twelve could be headwater reservoirs on tributaries to the main stem between Cairo, Illinois, and Arkansas City, Arkansas. To allow for other combinations of storms that could produce the project design flood, many more reservoirs would be required. The required acre-feet of storage in the many reservoirs that must be provided would have to be allocated exclusively for flood-control benefits in the Lower Mississippi River Valley. The operation and maintenance of this large number of reservoirs to achieve the desired reduction in the flow line would be extremely complicated and expensive in terms of manpower and funds.

Increasing the Hydraulic Capacity of the River by Dredging—The practicability of lowering the Project Design Flood Flow Line on the Mississippi and Atchafalaya Rivers by channel dredging beyond that presently embodied in the adopted plan was considered. This alternative would disturb the equilibrium of the rivers, adversely affect navigation, and create numerous unpredictable problems, making this alternative questionable from an engineering feasibility standpoint. The estimated cost would be in excess of 3.5 billion dollars.

Increasing the Hydraulic Capacity of the River with Additional Cutoffs—The flood-carrying capacity of the Mississippi River in the affected reach could be increased by reducing the present channel length. Investigations indicate 14 locations where successful cutoffs would shorten the river approximately 78 miles in the reach between Helena, Arkansas, and Baton Rouge, Louisiana. Based on experiences with the previous cutoffs, an allowance of 25 miles has been made for length regained before alignment control could be achieved. The net reduction in river length for the cutoffs considered would lower the adjusted flow line approximately 3 feet. The estimated cost of the cutoffs including relocations and channel improvements would be 1.4 billion dollars. This estimate is based on the assumption that all these cutoffs would develop satisfactorily into the main river channel. Since the 3-foot lowering in the flow line would not be adequate, the cutoffs would have to be combined with other measures such as channel dredging, additional floodways, or higher levees. The Atchafalaya River is a relatively straight river; therefore, sites for cutoffs to lower the flow line in the Atchafalaya Basin are not available. The least costly combination under this alternative would be the 14 cutoffs combined with levee raising at a total estimated cost of 1.8 billion dollars.

Diverting Flood Flows—An additional floodway to divert Mississippi River floodwaters and adequately lower the Adjusted Project Design Flood Flow Line was also considered. The diversion of flow would be required at about the latitude of Arkansas City, Arkansas, to reduce stages in the affected reach. The floodway would be located in the Boeuf Basin, roughly following the Boeuf River, and emptying into the lower Red River. A control structure would be required with a floodway averaging 7.5 miles wide and 150 miles long with guide levees. Extensive relocations would be necessary because of the many highways, railroads, drainage canals, utilities servicing the well-populated area, and numerous homes and businesses in the floodway. This floodway was studied in great detail in the 1920's and was subsequently rejected as being unacceptable and abandoned by Committee Document No. 1, 74th Congress, 1st Session, 1935. It would be even less acceptable today.

To supplement the existing floodway capacity of the Atchafalaya Basin, an additional floodway to divert excess flows from the Atchafalaya River westward at the latitude of Krotz Springs, Louisiana, was considered. The floodway would be approximately 3 miles wide and 55 miles long, cutting through the Teche Ridge and down the Vermilion River, emptying into Vermilion Bay. A control structure would be required at the upstream end of the floodway.

The estimated cost of this alternative for the Mississippi and Atchafalaya Rivers would be in excess of 2 billion dollars. Under this alternative, valuable land now provided protection would be contained within the floodways and would be subjected to flooding.

Widening Existing Floodways—Consideration was given to increasing the flood-carrying capacity of the Mississippi River by widening the leveed channel. This would require that the main stem levees be set back from 2 to 6 miles throughout the affected reach from about Helena, Arkansas, to Baton Rouge, Louisiana. This would be much more expensive than raising the existing levees. No additional consideration has been given this alternative as its cost would be prohibitive.

Consideration was also given to widening the existing Atchafalaya Basin Floodway by construction of a new levee approximately 3 miles east of the existing east guide levee, providing an outlet east of Morgan City, Louisiana. Morgan City would have to be provided additional protection by back levees as the city would be completely surrounded by water during a flood.

The total cost of this alternative for the Mississippi and Atchafalaya Rivers would be prohibitive and would result in flooding valuable lands and improvements for which protection is now provided.

Conclusions—The lower Mississippi River is a dynamic hydraulic system being changed by continuing physical processes. Since 1948 a trend of decreasing channel capacity has been noted for small to moderate floods, but these lesser flows did not provide the data needed to check flow capacities and to verify the flow line for high flood discharges. It has taken the large flood of 1973 to broaden the data base sufficiently to substantiate the positive deterioration in channel capacity and to permit a quantitative analysis of the adjustment required to be made to the original Project Design Flood Flow Line to protect the Valley against flood flows of project flood dimension. Obviously, a higher Project Design Flood Flow Line requires higher levees or other compensating means of flood prevention.

An examination of the alternatives results in the conclusion that the levee-raising plan is the most reliable plan, the least costly, and the most environmentally acceptable. The levee-raising plan has the additional major advantage of not reducing the currently protected area and has no adverse effects on navigation. This levee raising is now under way. It is recommended that it be funded to the full capability of the Corps.

NEED FOR MORE EXTENSIVE FLOOD PROTECTION

Although flood-control projects throughout the Mississippi River Basin protected almost 15,000,000 acres in 1973, there were almost 17,000,000 acres flooded. Obviously, flood protection for part of this area will not be justified in the foreseeable future. Some considerable part of the area may warrant protection since the damages sustained are estimated to be over $1,100,000,000.

The need for additional flood protection throughout the basin is indicated by the areas flooded and damages sustained. It is recommended that the Corps continue to work with local interests within the boundaries of proper procedure to secure additional protection where justified.

FUSEPLUG LEVEES

Backwater areas, partially protected by fuseplug levees which will be overtopped before the project flood crest arrives, are an integral part of the MR&T Flood Control Plan. Theoretically, the storage capacities of these areas are needed to enable the main-line levees to contain the project flood. When the flood-control project was conceived, most of these areas were relatively uninhabited and undeveloped. Since then, an influx of people and improvements has taken place. Allowing these areas to be "sacrificed" in the interest of the remainder of the Valley will meet with strong resistance and is a real problem.

Elimination of fuseplug levees is desirable but cannot be done without making other compensating changes in the flood-control plan. It is recommended that ways to achieve these compensating changes be studied.

OLD RIVER LOW-SILL CONTROL STRUCTURE

The loss of a training wall on this structure during the 1973 flood and the subsequent scouring that occurred jeopardized the integrity of the structure through the flood period, and because of its critical importance also jeopardized the integrity of the MR&T Project.

Emergency repairs have been made and studies are presently under way to determine the stability and adequacy of the structure.

EARLY COMPLETION OF THE MR&T PROJECT

The MR&T Flood Control Project has been under construction for well over 40 years. Some essential major elements of the project are still incomplete, i.e., Levees and Channel Improvement. Until the main-line levees are all brought up to grade and section and the main river channel is more effectively stabilized, the lower Valley will continue to be subject to devastation, and periodic emergency measures can be expected to recur.

It is recommended that completion of the authorized flood-control projects be expedited by funding the project to the full capability of the Corps of Engineers.

SEEPAGE

Seepage is one of the oldest and most familiar flood problems which intensifies with increased duration and height of the flood. Underseepage is the most widespread, but through seepage does exist particularly with sandy levees and for floods of long duration. There are standard means of treating levee slope seepage and boils which are intended to maintain the integrity of the levee.

It is concluded that seepage control measures should continue to be constructed where required to safeguard the levee system.

PUMPING

Throughout the basin there are many areas protected from headwater and backwater flooding which rely on gravity drainage structures as interior drainage outlets. During floods these structures are closed and the impoundments of seepage and rainwater often cause interior flooding of serious proportions. In some cases, pumping stations are authorized which will solve the problem. Studies should be made which will include the additional cost of emergency pumping during times of flood.

Care should be exercised to insure that submarginal lands are not protected by pumping, i.e. the sump area. Floodplain management should consider restricting the development of submarginal lands (sump areas) requiring protection.

PIPES THROUGH AND UNDER LEVEES

Experience during the 1973 flood and previous floods has shown that pipes and culverts through or under levees are definitely potential trouble spots in time of flood. This is particularly true with very old pipes that may have deteriorated through the years. Ideally, all pipes should be removed and installation of new ones forbidden. Since this is probably impracticable for most levee systems, special attention must be given both existing lines and the design of new ones.

Deteriorating pipes constitute a real flood hazard. As a minimum, an inventory should be made of all existing pipelines which should be inspected with a view toward having any discernable deficiencies corrected. It is recommended that design of new installations be such that they present the minimum hazard during floods.

LEVEE EROSION FROM WAVE WASH

Levee slope erosion from wave wash occurred in many places both on the Mississippi River and/or Tributary levees during the 1973 flood. The most serious damage was done at locations where a wide expanse of water with minimum vegetation bordered the levee. More and more of the foreshore area between the levee and the river is being cleared and cultivated. In some places the open expanse of water, during overbank stages, is several miles wide. Winds across these open waters can and do cause waves which can erode and dangerously weaken a good levee in a very short time. Normal sod on the exposed slope is not enough protection. Special slope protection may have to be constructed at some locations. Tree screens are helpful.

It is recommended that tree screens be encouraged and that consideration be given to constructing levee slope protection in the most critical areas.

CHANNEL DETERIORATION ON TRIBUTARY STREAMS

Data collected during the flood indicate that tributary streams in the alluvial plain which are downstream from reservoirs are rapidly filling. The implications of such a development, as shown by the discussion on pages 63-68 for the lower Mississippi River, are far reaching and may be extremely serious. This problem emphasizes the urgency of improving stream and bank erosion control technology.

It is recommended that the possibility of channel deterioration and possible serious implications therefrom be recognized by all Corps offices having responsibility in this field.

LIAISON WITH ARMY COMMANDERS

The flood demonstrated the importance of keeping the supporting Army Headquarters briefed when any support from them is committed.

ALL-WEATHER ACCESS ROADS

It was found during the 1973 flood that all-weather access roads to flood-control structures are a vital necessity. Some of the roads which were not all-weather were surfaced during the emergency.

It is recommended that the program of providing all-weather access roads on levees be expedited to the maximum extent practicable.

STONE STOCKPILES FOR EMERGENCY USE

It was found that the available stone stockpiles were advantageous during the flood fight. Stone was in short supply in some areas because of quarry locations and transportation problems.

It is recommended that stone stockpiles, if not already committed, be established at critical locations.

MAINTENANCE SUPPORT FOR ARMY VEHICLES

Several Districts were able to obtain vehicles from Army units adequate to meet their needs. However, they all reported that a problem existed in maintaining these vehicles since parts were not readily available commercially. Emergency operations performed subsequent to the 1973 flood have demonstrated that a request for vehicles should include maintenance capability. This procedure has worked very well.

It is recommended that advance arrangements be made for securing necessary parts and maintenance expertise as needed for Army vehicles borrowed during times of emergency.

BETTER MAINTENANCE OF ALL FLOOD PROTECTION WORKS

Every flood clearly demonstrates the importance of proper maintenance, whether it be by Corps of Engineers or local interests, of all flood-control structures. The 1973 flood was no exception.

It is recommended that emphasis on the importance of proper maintenance of all flood-control structures be increased.

AFTER-ACTION CONFERENCE

The 1973 Adjusted Project Flood Flow Line analysis impacts heavily on Federal and non-Federal investments for flood protection. Therefore, it was decided to approach some of the best qualified hydraulic engineers and potamologists in engineering practice and the academic field to acquaint them with the problem of changing flow lines in the unstable Mississippi River and to solicit their views and recommendations. On 11 April 1974, a conference was held with Dr. Vito A. Vanoni, California Institute of Technology; Dr. Daryl B. Simons, University of Colorado; Dr. Alvin Anderson, St. Anthony Falls Laboratory, University of Minnesota; the Committee on Channel Stabilization; and representatives from HEC, OCE, WES, and Missouri River Division in attendance. The consensus of the conferees was that the analysis as presented was reasonable and adequately conducted and that further and more detailed studies should be undertaken to refine certain areas of the analysis of the flow line. These studies have been formulated and are being conducted. The conferees were also requested to make recommendations relative to direction for ongoing and future potamology, channel improvement, and hydraulic studies to arrive at a solution to prevent or minimize future losses in channel capacity. A potamology program and plan of study have been formulated and initiated, incorporating the recommendations of the conferees.

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