Evolution of the Levee System Along the Lower Mississippi River

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...Ten thousand River Commissions...cannot tame that lawless stream...cannot say to it, "Go here," or "Go there," and make it obey.

- Mark Twain

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INTRODUCTION

- The levee system has been present along the Mississippi River since the first Europeans settled the region, but its design has changed many times since that first levee.
- The changes were brought about mainly by flooding, which in turn drove other factors such as costs and politics.
- Technology has also played a role in this development.

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LEVEES

- Earthen embankments built on the natural levees parallel to the river channel and designed to protect the area behind it from high flows in the main channel
- Levees must be high enough to prevent overtopping and broad enough to resist deterioration from hydraulic piping

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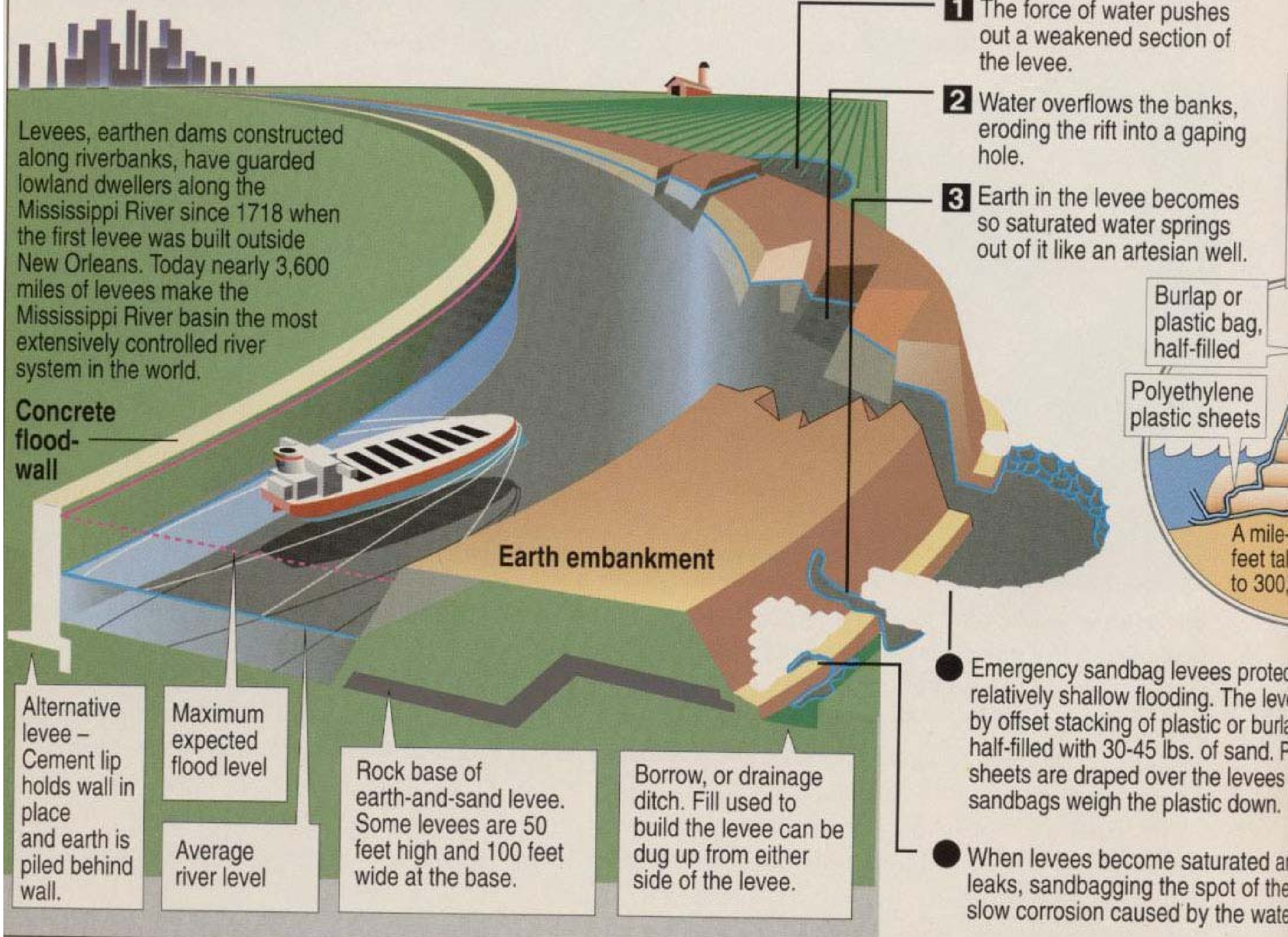

Levees: the first and last defense

How levees protect lowlands and how things can go wrong, and what is done once they do

Levees, earthen dams constructed along riverbanks, have guarded lowland dwellers along the Mississippi River since 1718 when the first levee was built outside New Orleans. Today nearly 3,600 miles of levees make the Mississippi River basin the most extensively controlled river system in the world.

Three ways levees fail:

1. The force of water pushes out a weakened section of the levee.
2. Water overflows the banks, eroding the rift into a gaping hole.
3. Earth in the levee becomes so saturated water springs out of it like an artesian well.

Concrete flood-wall

Earth embankment

Alternative levee – Cement lip holds wall in place and earth is piled behind wall.

Maximum expected flood level

Average river level

Rock base of earth-and-sand levee. Some levees are 50 feet high and 100 feet wide at the base.

Borrow, or drainage ditch. Fill used to build the levee can be dug up from either side of the levee.

Burlap or plastic bag, half-filled

Polyethylene plastic sheets

A mile-lo[…]vee, 5 feet tall, [...] take u[…] to 300,00[…]gs.

- Emergency sandbag levees protect [...] relatively shallow flooding. The levee[s are] made by offset stacking of plastic or burlap [bag]s, half-filled with 30-45 lbs. of sand. Po[l]ylene sheets are draped over the levees a[nd m]ore sandbags weigh the plastic down.
- When levees become saturated an[d spr]ing leaks, sandbagging the spot of the [bre]ach may slow corrosion caused by the water[.]

OVERTOPPING

Levees are often overtopped where they have experienced differential settlement; generally where underlain by soft soils, such as old oxbow fills or peaty bulrush marsh deposits.

CREVASSE is the term applied to breaks where underseepage has caused the levee to collapse

Federal Levee L246 at RM 241 on the Missouri River.

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SCOUR

Scour from local eddified flow often occurs at steep drops, around, or over flow obstructions, as shown here.

Mississippi River Drainage Basin

- The Mississippi River drains 41 percent of the continental United States, stretching from Montana and Canada to western New York.
- The basin covers more than 1,245,000 square miles, includes all or parts of 31 states and two Canadian provinces

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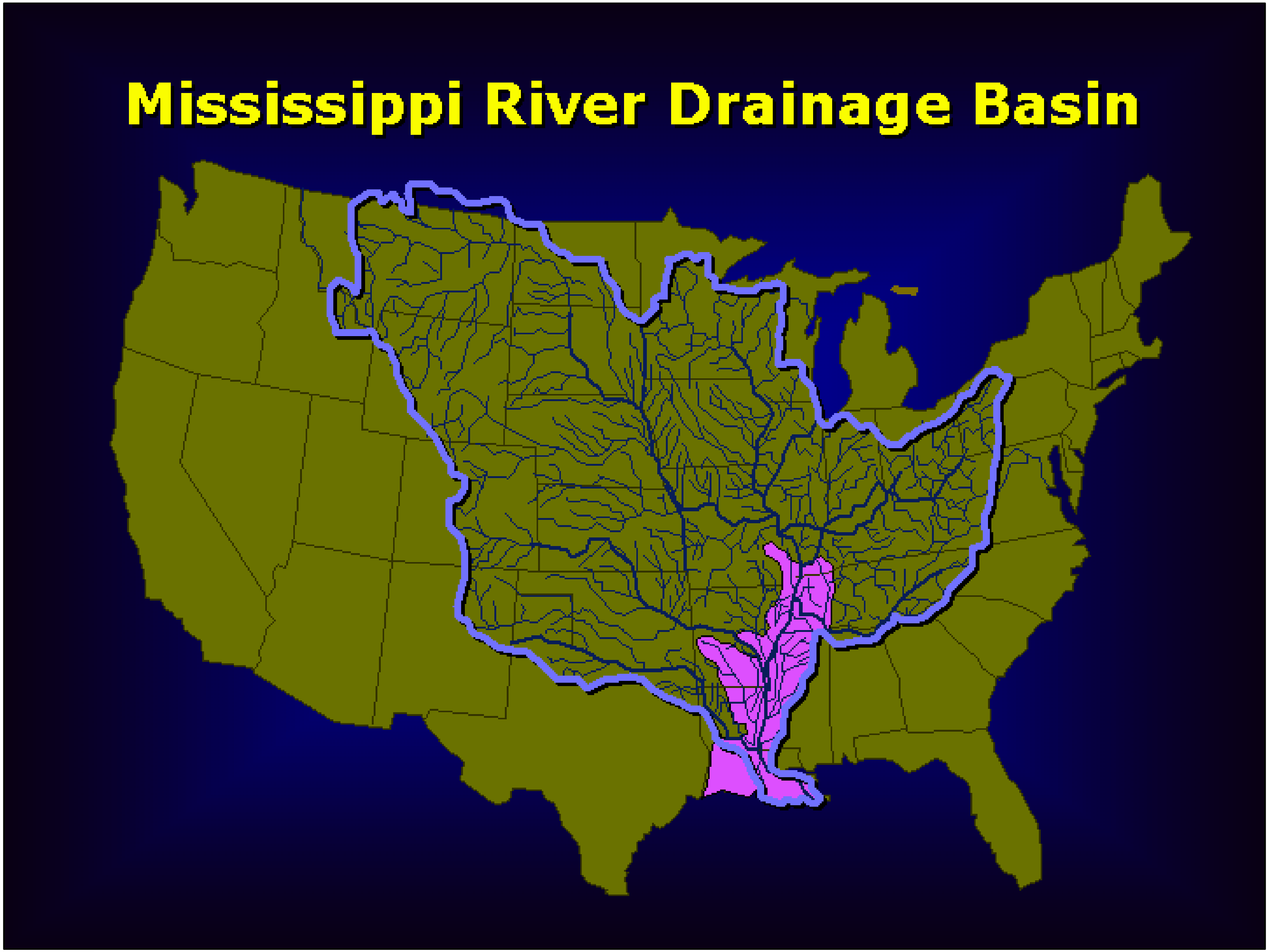


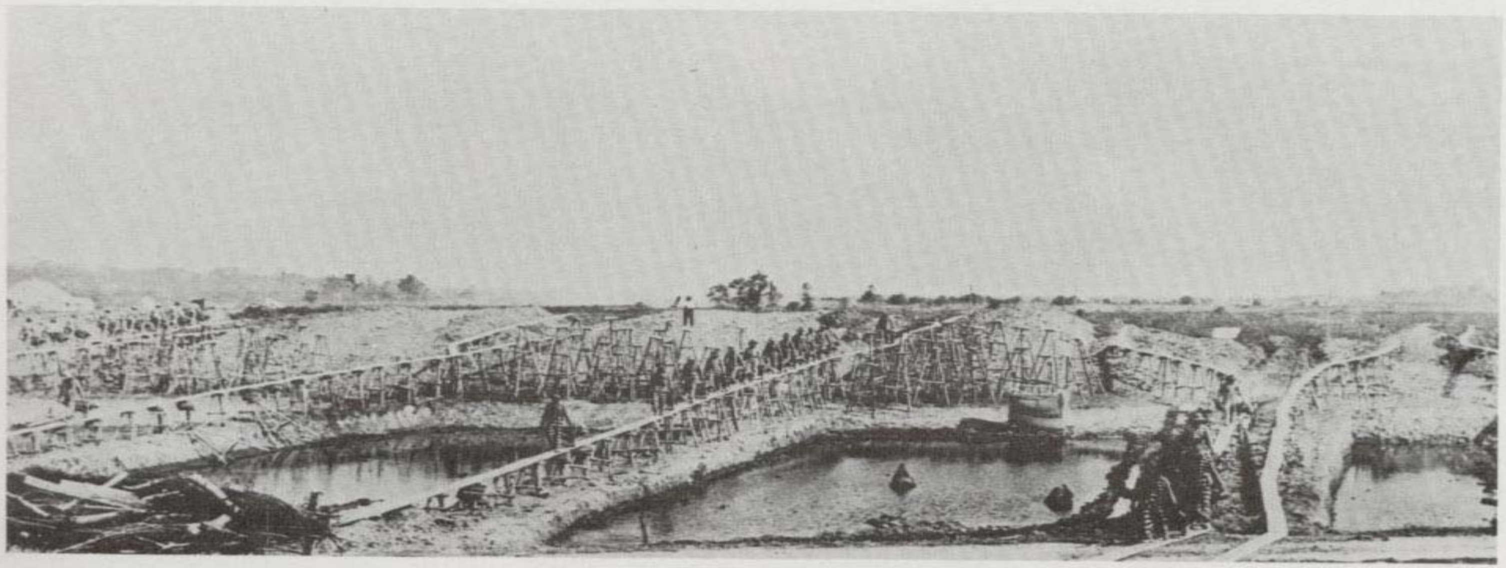
UMR Areas subject to flooding along the Lower Mississippi shown in pink

You hardly ever see the river, but the levee is always close by, a great green serpent running through woods, swamps, and farms, with towns nestling close to its slopes. The levee is unobtrusive, since its slope is green and gradual, but in fact it is immense -- higher and longer than the Great Wall of China, very likely the biggest thing that man has ever made....It was the principal human response to the titanic power of the great river.

-- Alan Lomax, The Land Where the Blues Began

FIRST MAN-MADE LEVEE

- **Levee construction began with the first settlers along the Mississippi River**
- **Between 1718-27 a levee was built around New Orleans modeling those in France**
  - **It was 5400 ft long ,18 ft wide at the crown with a roadway 4 ft high, and had a slope of 1:2**



Building levee by wheelbarrow

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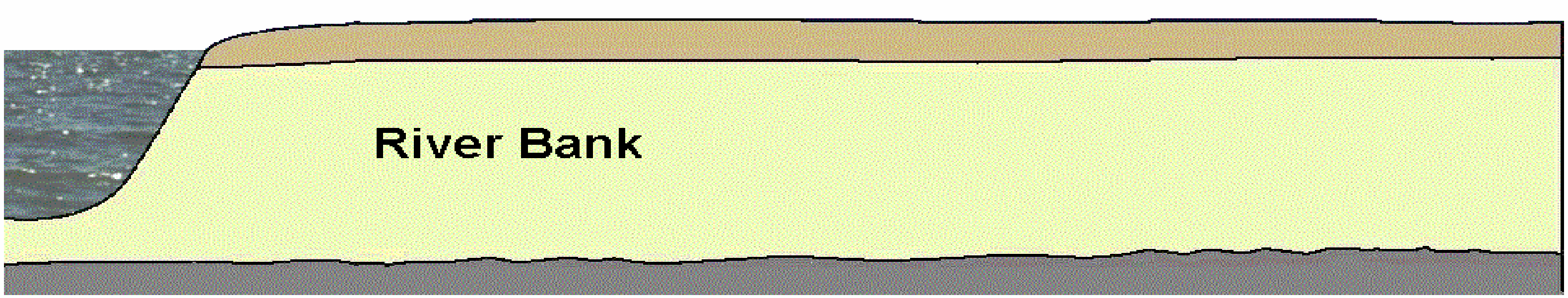
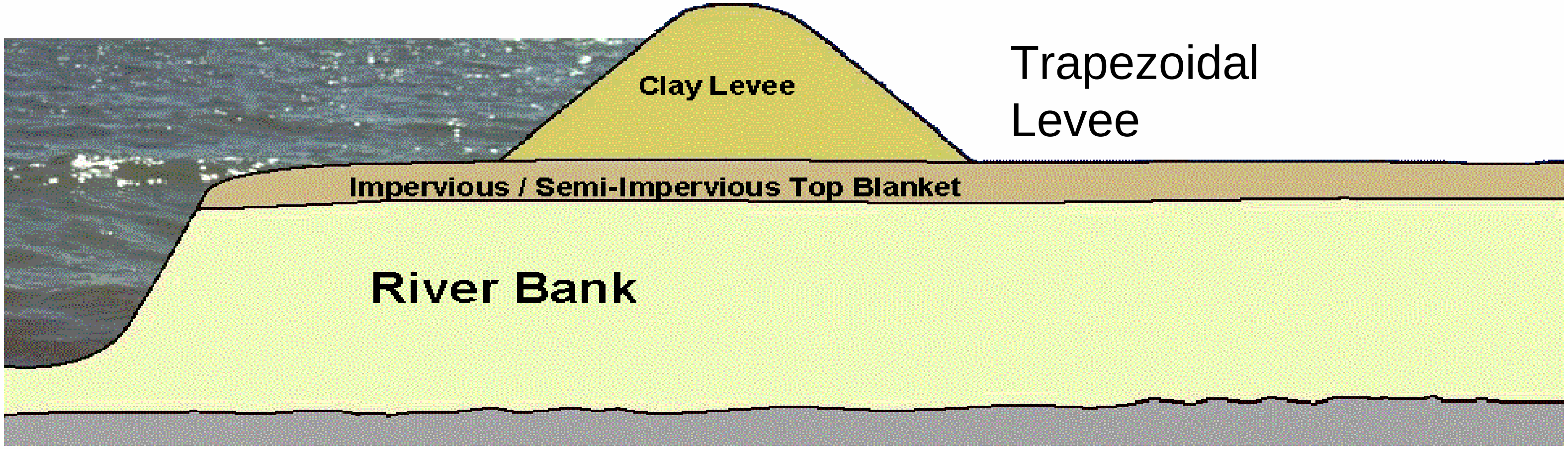
EARLY LEVEE CONSTRUCTION

- State governments made it policy that farmers built their own levees along the areas they owned along the Mississippi River
- Haul methods would yield 10-12 cubic yds per day with a haul limit of 75 feet

Mules and wagons are used to construct levees in the St. Francis Levee District in 1909.

EARLY LEVEE CONSTRUCTION





Trapezoidal
Levee

URBAN LEVEES

Levee construction at New Orleans in 1863, during the Civil War.

RAISING LEVEES

The levees along the lower Mississippi had to be heightened continuously between 1850 and 1927 because the bed of the Mississippi River elevated itself, because of increased confinement, caused by levee construction.

Early Federal Legislation

- In 1820 the first Federal Government involvement along the Mississippi River focused on navigation, not flood control
- Disastrous floods along the lower Mississippi and its tributaries in 1844, 1849, and 1850 resulted in the Swamp Acts of 1849-1850

Swamp Acts of 1849-1850

- **First federal involvement for flood control along the Mississippi River**
- **First Act gave Louisiana all swamp and overflow lands within its boundaries that were unfit for cultivation**
- **Second Act did the same for Arkansas, Missouri, Illinois, and Mississippi**

State	Land Given (sq. mi.)
Illinois	2,277
Missouri	5,230
Arkansas	12,010
Mississippi	5,141
Louisiana	14,740

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Swamp Acts of 1849-1850

- **The lands were to be sold to the public and the money generated to be used to construct levees and drainage for the reclamation of the lands**
- **Lack of coordination between states and levee districts resulted in the levee lines being a failure**

State	Levee Design Criteria
Louisiana	Crown 1/3 of base Side slope 1:2
Arkansas	Height = 30” above overflow Crown width = height Base width = 7 x height
Mississippi	Side slope 1:6 on riverside 1:2.5 on landside

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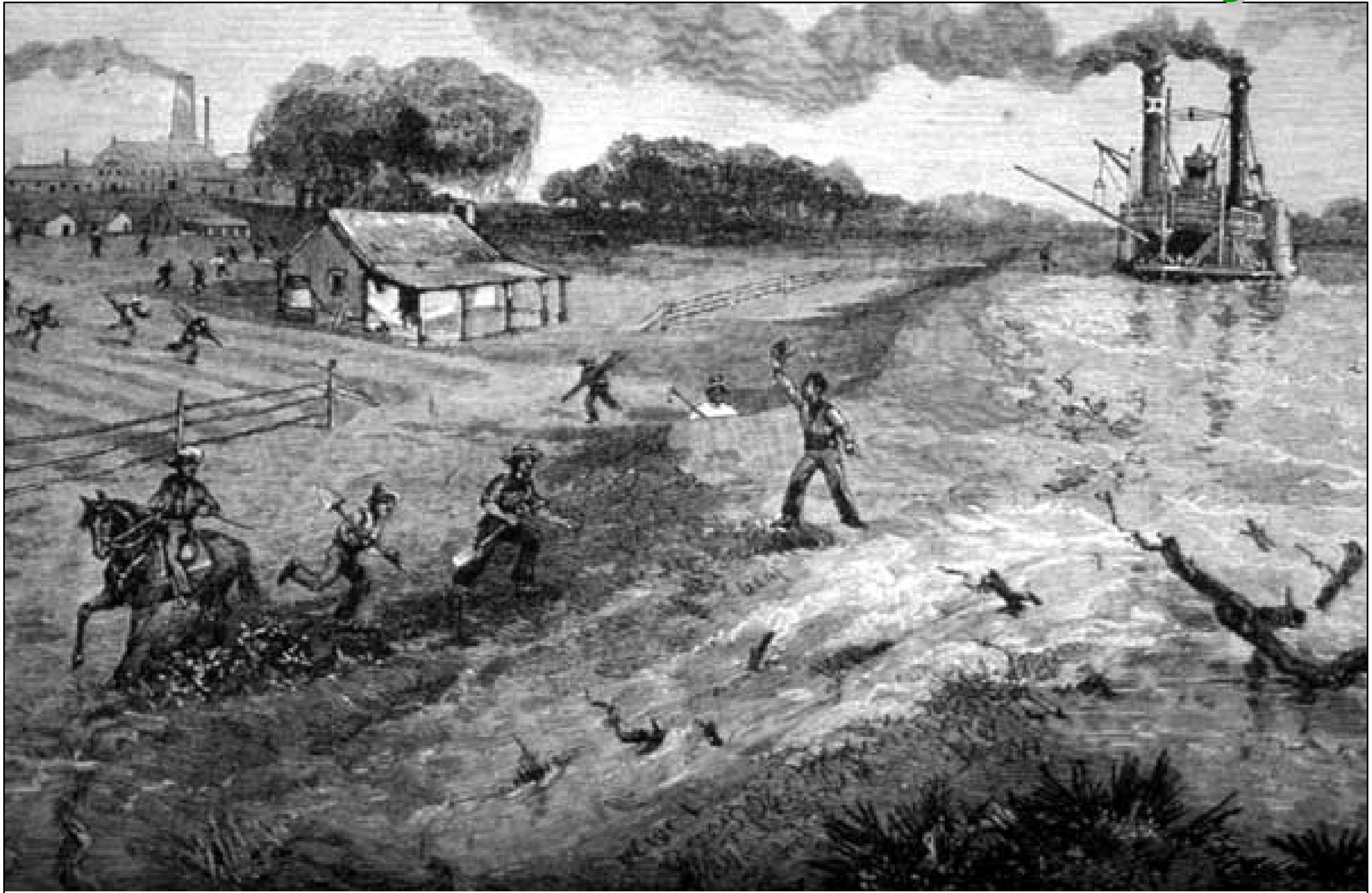
Levees are an inherent liability



The advantages of reclamation came at considerable risk. Drawing by J. O. Davidson in *Harper's Weekly*, March 5, 1884.

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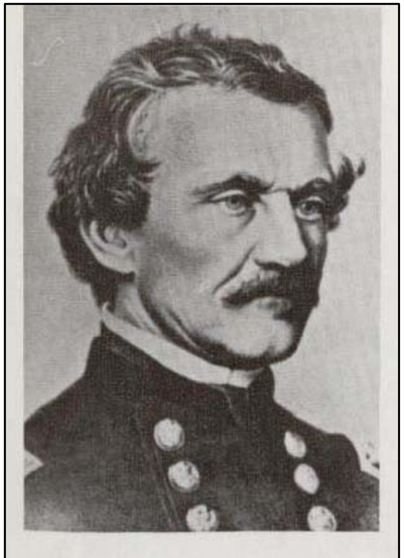
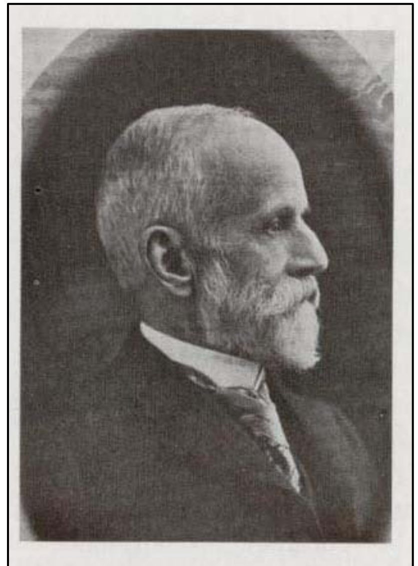
1850 Mississippi River Surveys



A. A. Humphreys



Henry L. Abbot

- **In 1850 Congress appropriated $50,000 to conduct two hydrographic and topographic surveys of the Mississippi River; one by a civilian and the other by a civilian**
- **One survey was conducted by Army Engineers A. A. Humphreys and Henry L. Abbot, but was not completed till 1861**
- **Civilian engineer Charles Ellet Jr. was also authorized to prepare an independent survey, completed in 1852**

- **The Humphreys-Abbot report considered three methods of flood protection:**
  - **Cutting off bends in the river**
  - **Diversion of tributaries and creating artificial reservoirs and outlets**
  - **Confining the river to its channel (the levee system)**
- **The conclusion was that the first two options were too costly and provided little advantage, thus the third option was recommended**
- **Their levee design called for freeboards 3-11 feet above the 1858 flood**

REPORT

UPON THE

PHYSICS AND HYDRAULICS

OF THE

MISSISSIPPI RIVER;

UPON THE

PROTECTION OF THE ALLUVIAL REGION AGAINST OVERFLOW;

AND UPON THE

DEEPENING OF THE MOUTHS:

BASED UPON

SURVEYS AND INVESTIGATIONS,

MADE UNDER THE ACTS OF CONGRESS DIRECTING THE TOPOGRAPHICAL AND HYDROGRAPHICAL SURVEY OF THE DELTA OF THE MISSISSIPPI RIVER, WITH SUCH INVESTIGATIONS AS MIGHT LEAD TO DETERMINE THE MOST PRACTICABLE PLAN FOR SECURING IT FROM INUNDATION, AND THE BEST MODE OF DEEPENING THE CHANNELS AT THE MOUTHS OF THE RIVER.

SUBMITTED TO THE BUREAU OF TOPOGRAPHICAL ENGINEERS, WAR DEPARTMENT, 1861.

[REPRINTED WITH ADDITIONS.]

PREPARED BY

CAPTAIN A. A. HUMPHREYS AND LIEUT. H. L. ABBOT,

CORPS OF TOPOGRAPHICAL ENGINEERS, UNITED STATES ARMY.

"I approve much more your method of philosophizing, which proceeds upon actual observation, makes a collection of facts, and concludes no further than those facts will warrant."—DR. FRANKLIN TO ABBÉ SOULAVIE.

WASHINGTON:
GOVERNMENT PRINTING OFFICE
1876.

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DETERIORATION of LEVEES

- The Civil War left the levees along the river in disrepair, exacerbated by severe floods in 1862 and 1865
- The 1867 flood caused an additional $3.9 million of damage to the levees, estimated that 9.75 million cu. yd. of fill would be needed to repair the levees
- 1874 flood resulted in the creation of a "Levee Commission" to survey the system and submit a plan for reclamation of the Alluvial Valley

Levee crevasse at Bonnet Carré, Louisiana.

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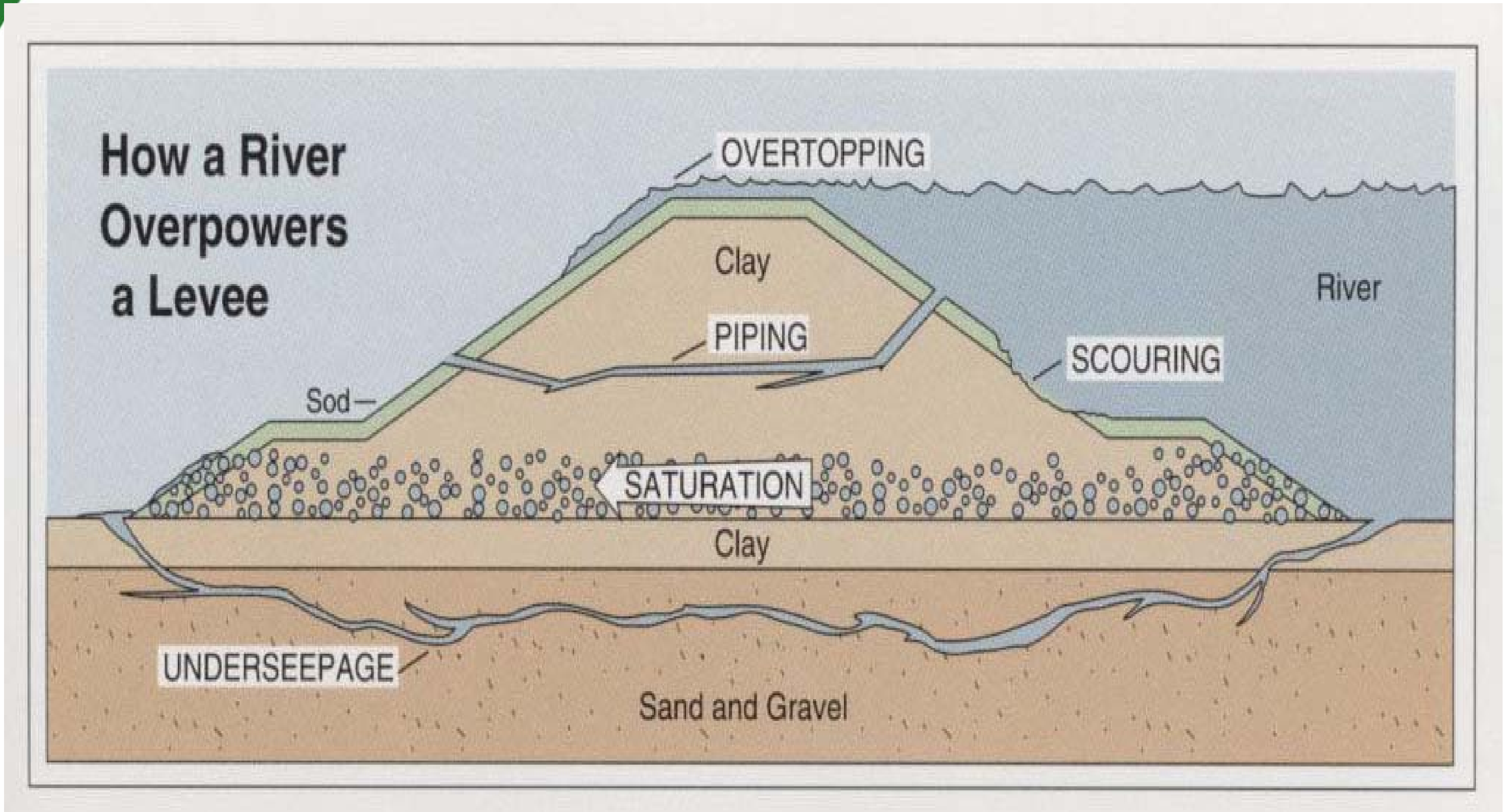

The most cited failure modes for levees include underseepage, hydraulic piping, and overtopping. In actuality, excessive uplifting seepage on the landside toe probably triggers mass liquefaction, which triggers extensive bearing capacity failure, which then causes a catastrophic slope failure. In this manner, 100 to 2000 lineal feet of levee can collapse in a few seconds; which is the usual pattern.

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MISSISSIPPI LEVEE COMMISSION

- Estimated it would take \$3.5 million (8 million cu. yd. of fill) to repair the levees
- It would take \$46 million (115 million cu. yd. of fill) to build the entire levee system
- Determined 5 defects in the levee system:
  - Vicious levee organization
  - Insufficient levee height
  - Injudicious cross-section and construction
  - Inadequate inspection and guarding
  - Faulty locations

St Louis Levee, 1867

—Missouri Historical Society

The St. Louis Levee, 1867, from a stereo by Boehl and Roenig.

MISSISSIPPI RIVER COMMISSION-1879

- The Mississippi River Commission was created by an Act of Congress in 1879
- General Humphreys argued against the MRC covering flood control, because he thought the Corps of Engineers should control the river
- Others argued that flood control should be a state issue
- Flood control was looked at as an integral part of river navigation
- According to the MRC, the greatest detriment to levees was river instability and bank caving

Caving bank on the Mississippi River.

Composition of the Mississippi River Commission (MRC)

- Legislation pushed by James B. Eads
- 7 members appointed by the President
  - 3 officers from Corps of Engineers; one of whom serves as chair and another as secretary
  - 3 civilians (at least 2 civil engineers)
  - 1 US Coast and Geodetic Survey (now NOAA)

Brevet Major General Quincy A. Gillmore

Mississippi River Commission (MRC)

- The study of and reporting upon the necessity for modifications or additions to the flood control and navigation project
- Recommendation of policy and work programs
- Recommendation upon any matters authorized by law, inspection trips, and holding public hearings

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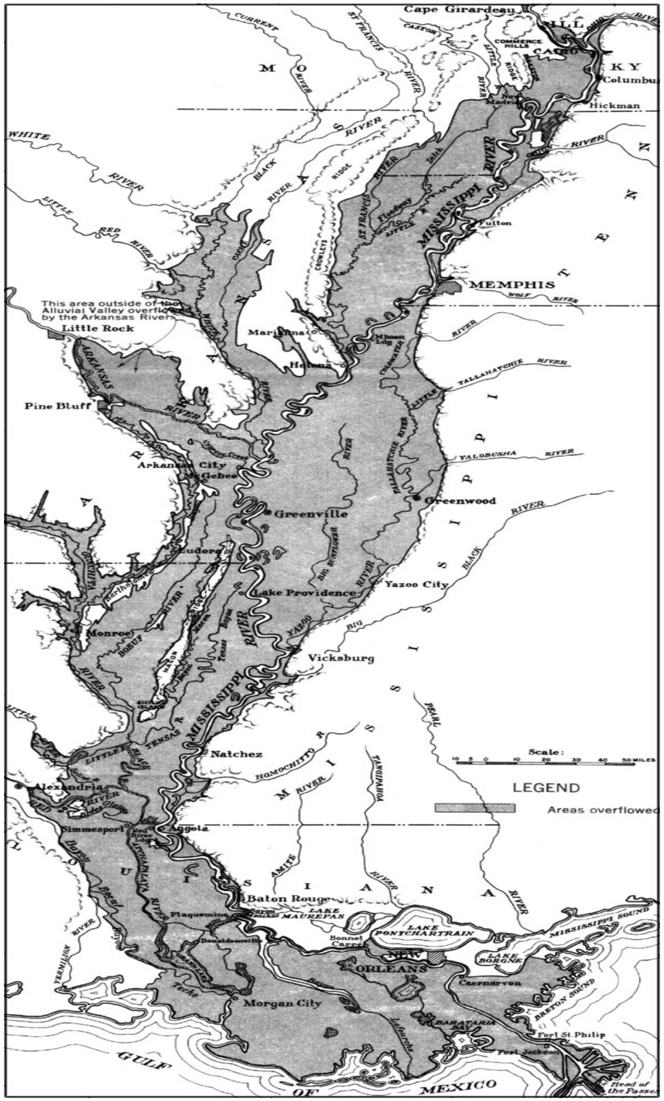
MRC ‘Levees Only’ Policy of 1882

- Construction of a levee line with grade sufficient to contain the frequent floods would result in “self-cleansing” of the river
- The closure of new breaks should be completed first, as old breaks had already done their maximum damage to the navigation

Flood of 1882; overflowed areas in the alluvial valley.



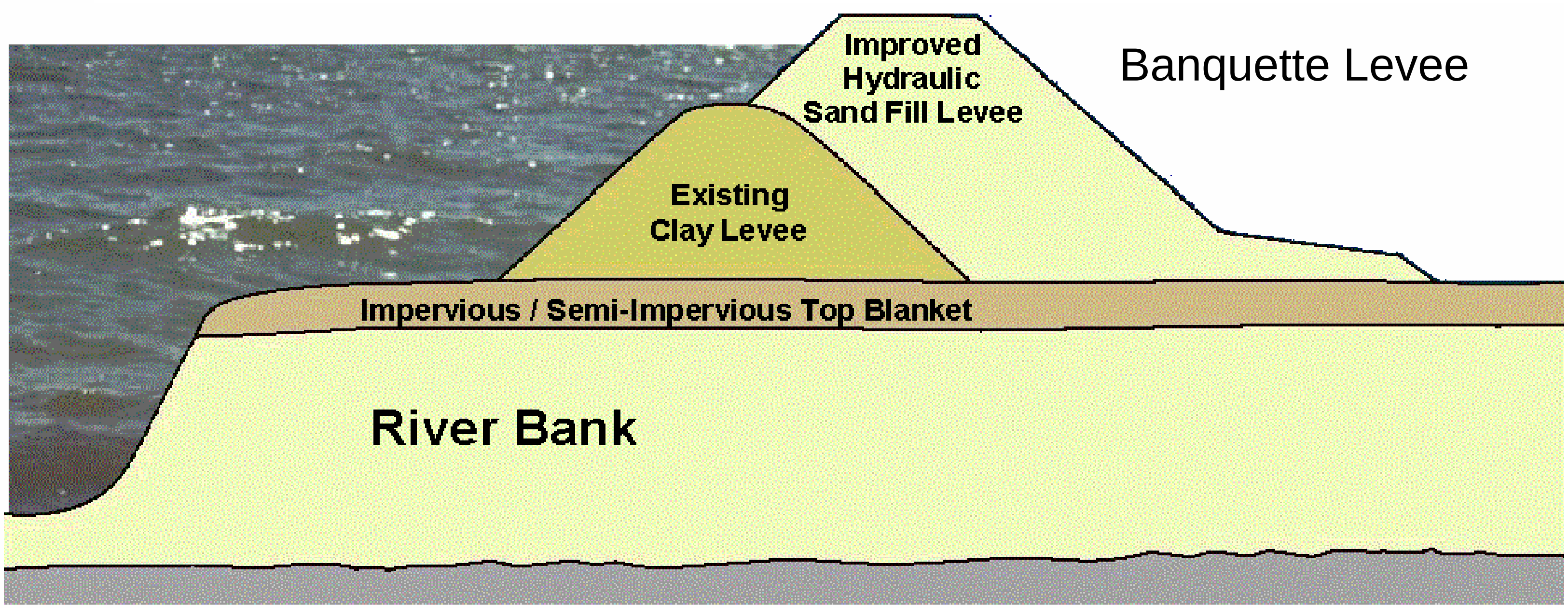
Mississippi River Flood of 1890

- **56 miles of levees destroyed**
- **The MRC adopted the flood of 1890 as the design flow line for levees**
- **Resulted in many levees needing to be raised from 38 to 46 feet**

The tragic figures reflect the hardship of the turn-of-the century floods

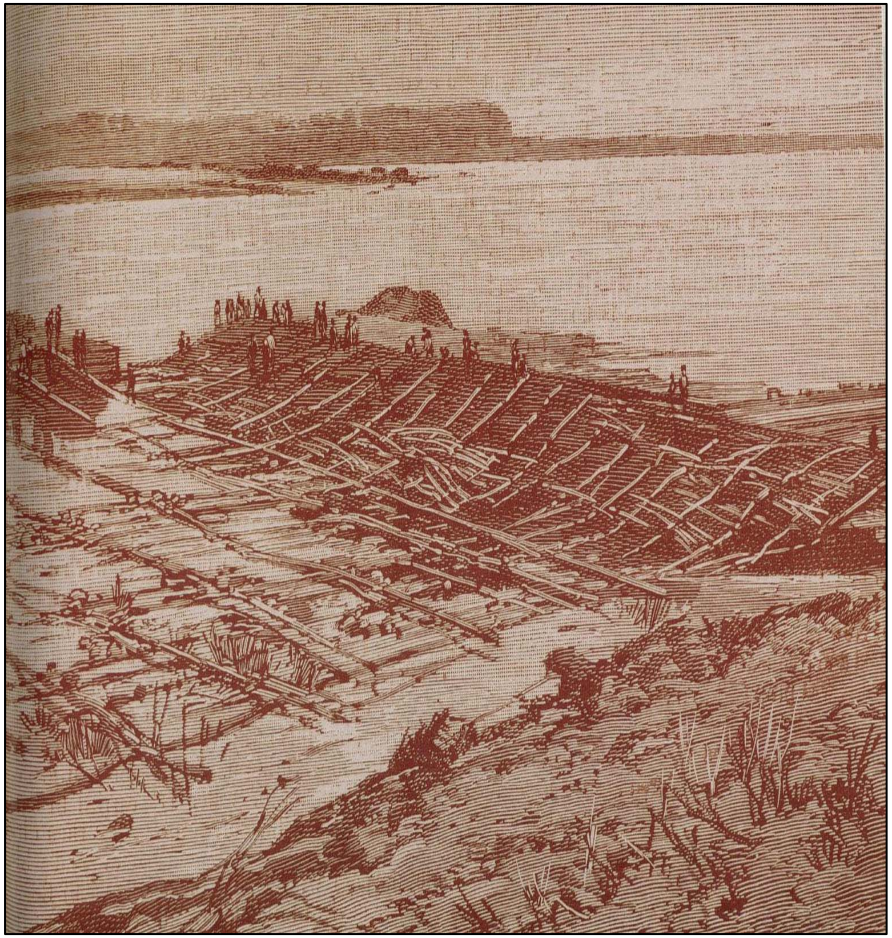
MRC Levee Standard

- **Crown Width 8 feet**
- **Riverside slope 1:3**
- **Landside slope**
  - **1:3 to height of 8’, then 1: 1:10 to height of 20’, then 1:4**



BANK REVETMENTS

- 1900-1910
  - 53 million cubic yards added by Federal Government
  - 73 million cubic yards added by private citizens
  - 21% (27 million cubic yards lost from bank caving and erosion
- MRC enacted the bank revetment policy to stave off the losses



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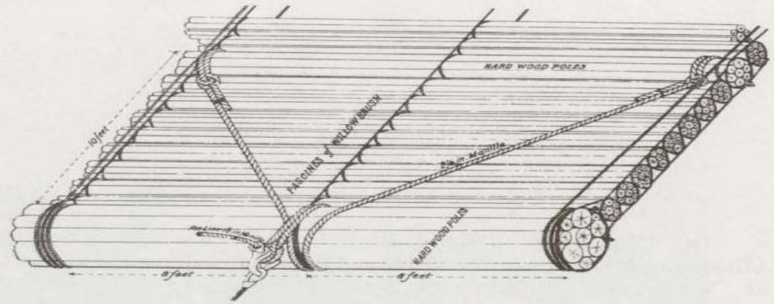
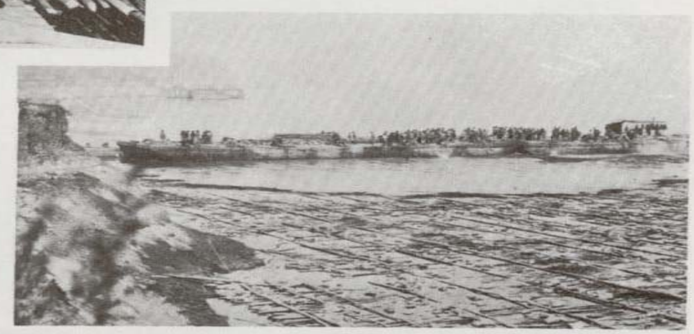
Early Fascine Scour Protection Matting

Fascine mat assembly



Mat is assembled by labor forces on the site

Rock is piled on floating mattress for ballast



Mat in place, remainder of willows are below water level

Mississippi River Flood of 1912

- **47% of the levees above Vicksburg were still sub-par, below MRC's 1890 standard**
- **53% of the levees on the tributaries were sub-par**

Hickman, Kentucky, during the 1912 flood.

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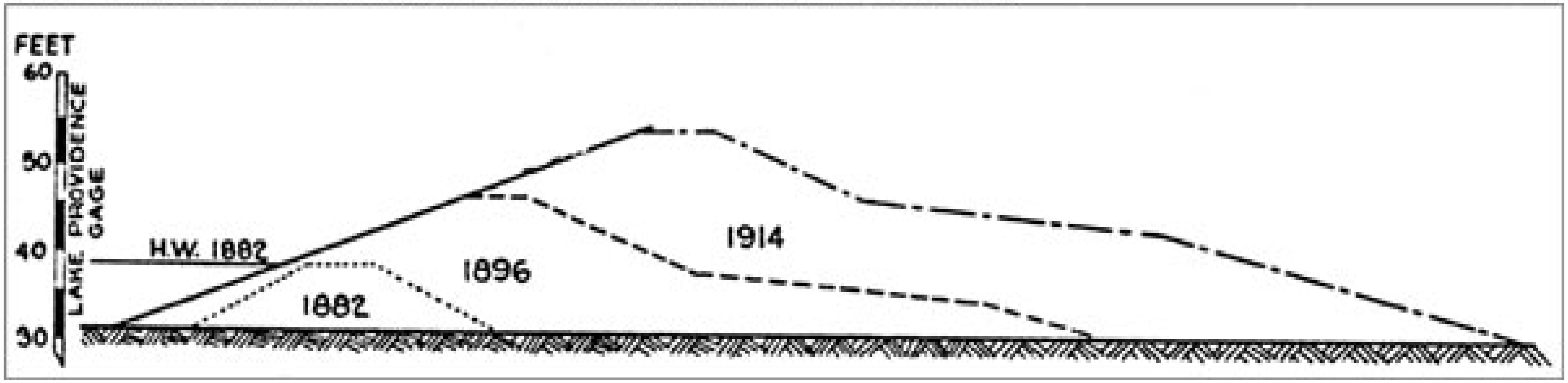
Mississippi River Flood of 1912

- Resulted in an increase in the levee grade and design cross section by 1914
- Grade 3' above 1912 floodline
- Banquette 3' – 8' below crown; width 20' – 40'

The evolution of levees grades and section from 1882-1914.



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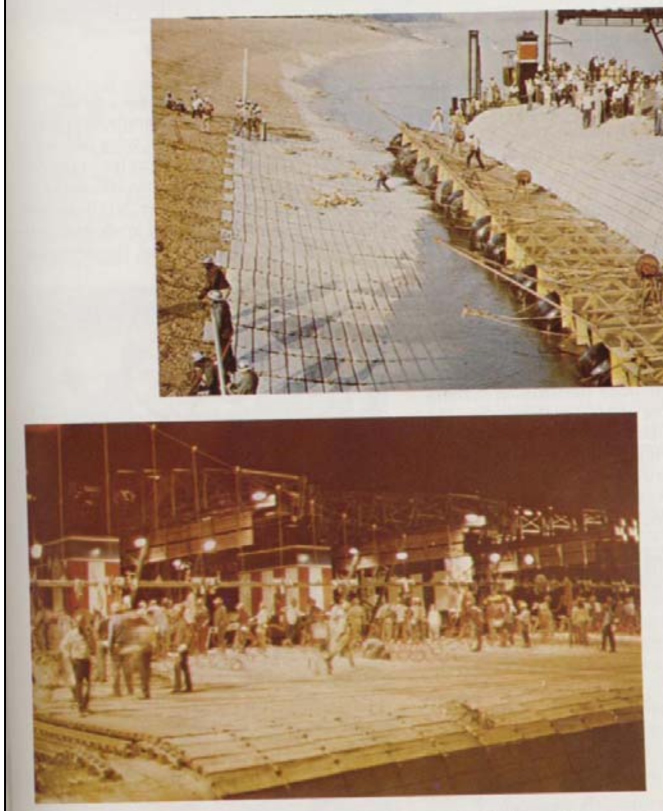
STRUCTURAL REVETMENTS

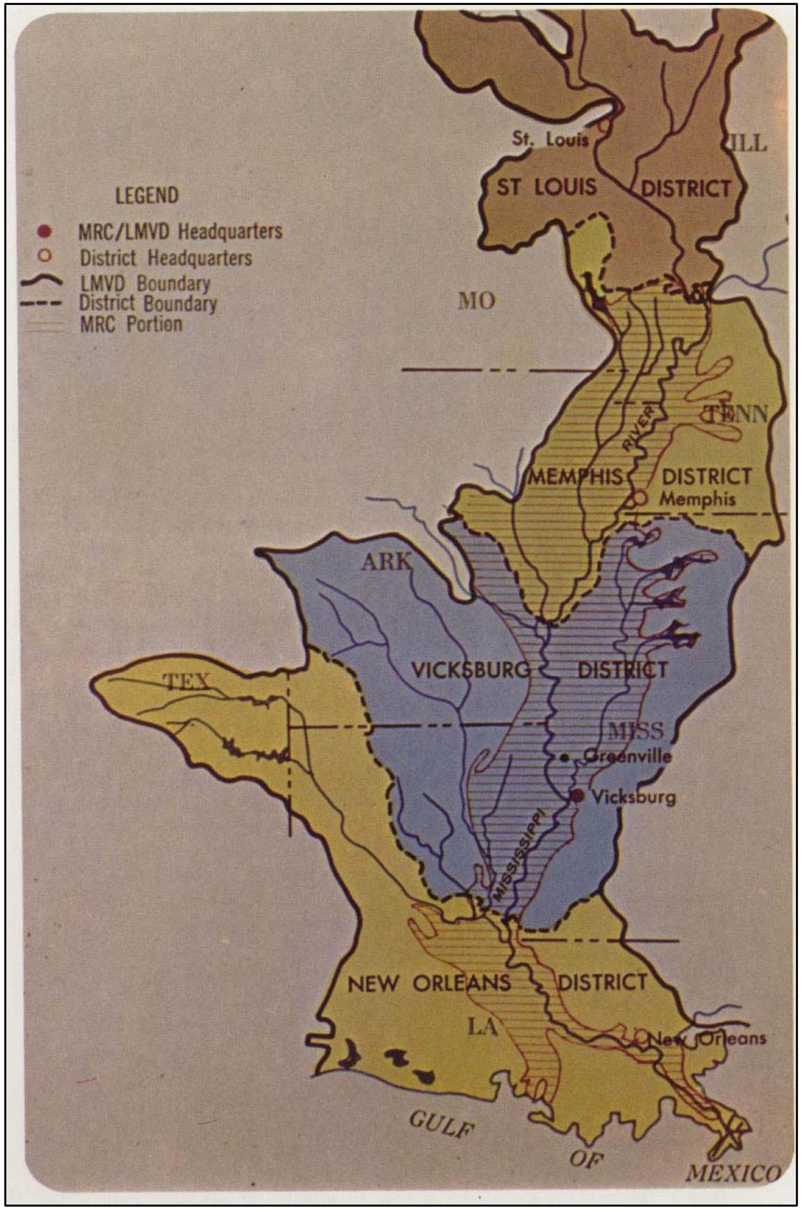
- Due to the high cost of bank stabilization the MRC changed their policy
- Levee location would now be used to counter bank caving
- Concrete matting (riverside) and sheet piling (foundations) would be used when a levee could not easily be moved back



The Vicksburg District's Mat Sinking Unit (above) plays an important role year after year in the overall flood-production plan. To maximize their results, the unit works around the clock (below)

MRC Span of Control Widens

- In 1906 the MRC planned levees from Cape Girardeau, MO south
- In 1913 MRC jurisdiction was extended north to Rock Island, IL
- 1915 MRC was required by Congress to report levee expenditures by local/state interests



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St. Louis Levee, 1916

The Saint Louis levee about 1916, showing the preemption of an urban riverfront for railroad use. View is looking north from the Municipal Bridge. Courtesy City Plan Commission, City of Saint Louis

First Federal Flood Control Act, 1917

- The First Flood Control Act had 3 provisions pertaining to levees
  - Levees built for flood control were authorized for the first time
  - Federal funds could be spent on levees on the tributaries
  - Local interests must contribute at least 1/3 of the cost to all federally funded levees and the local interests must maintain the completed levees
- In 1922 and 1923 MRC authority was extended to cover the tributaries from the river's mouth to Rock Island, as far as they were affected by flood waters of the Mississippi River

THE MECHANISM BY WHICH RIVER AND HARBOR AND FLOOD CONTROL PROJECTS ARE CONCEIVED, AUTHORIZED, AND CONSTRUCTED

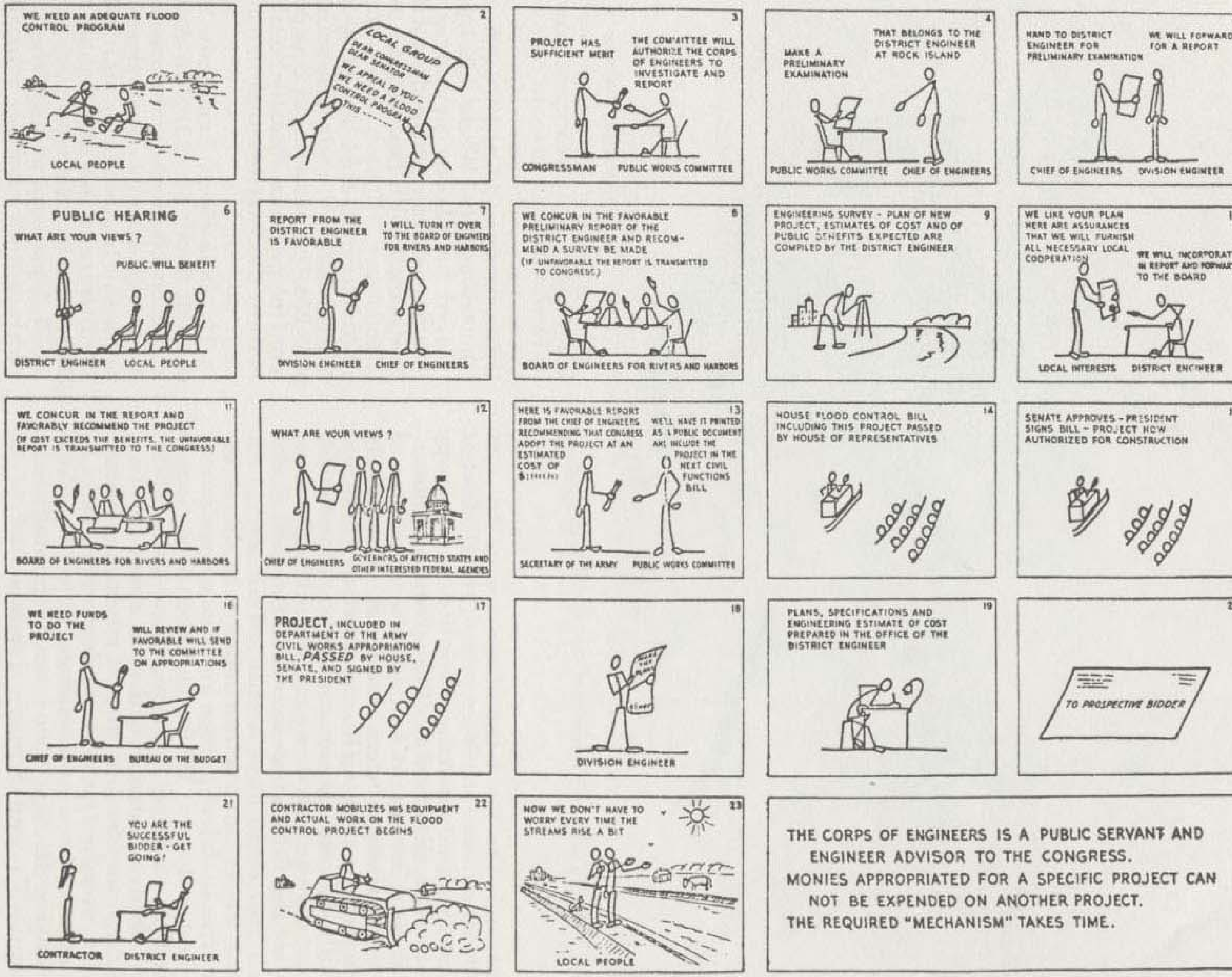
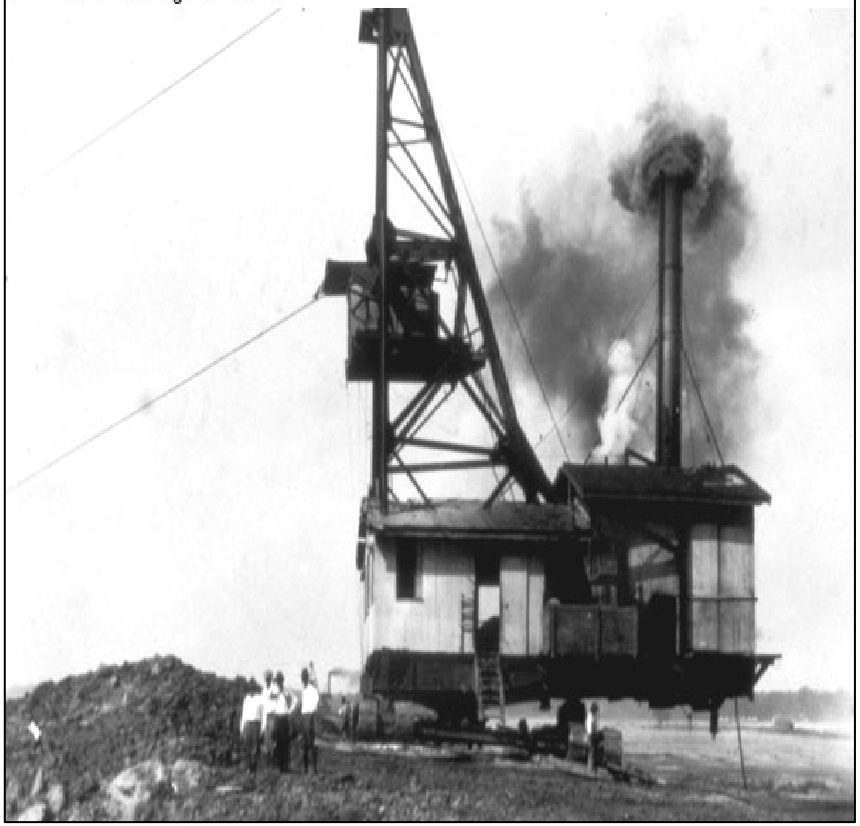


FIG. 64. A chart showing the steps necessary for a city or rural drainage district to obtain a flood control project.

MECHANIZATION

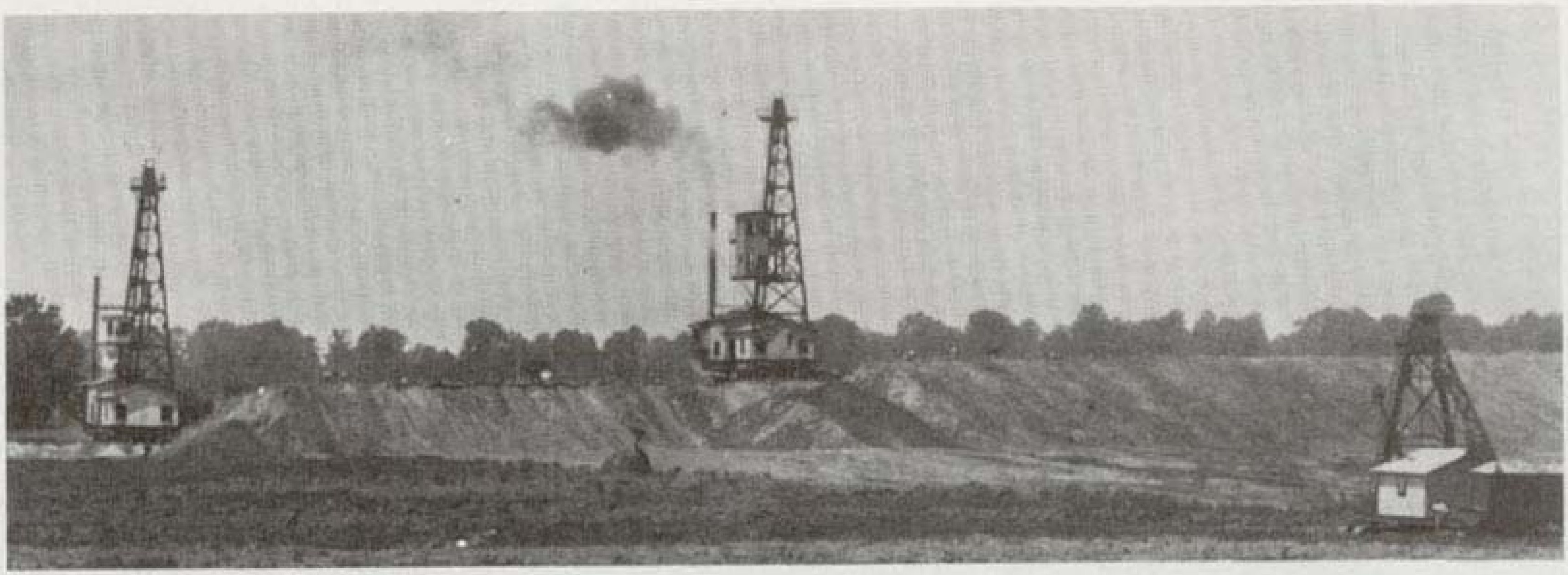
Tower machines and other technological advancements increased the rate of levee construction during the 1920s.



One of two giant cranes which made up a levee-raising "tower machine"

The 1920s saw widespread adoption of mechanized earth moving technology being applied to flood control structures and flood plain drainage.

CABLEWAY DRAGLINES REVOLUTIONIZE LEVEE CONSTRUCTION



The new concept of dual cableway machines greatly reduced the cost of levee building, making the earthen walls better values than ever before

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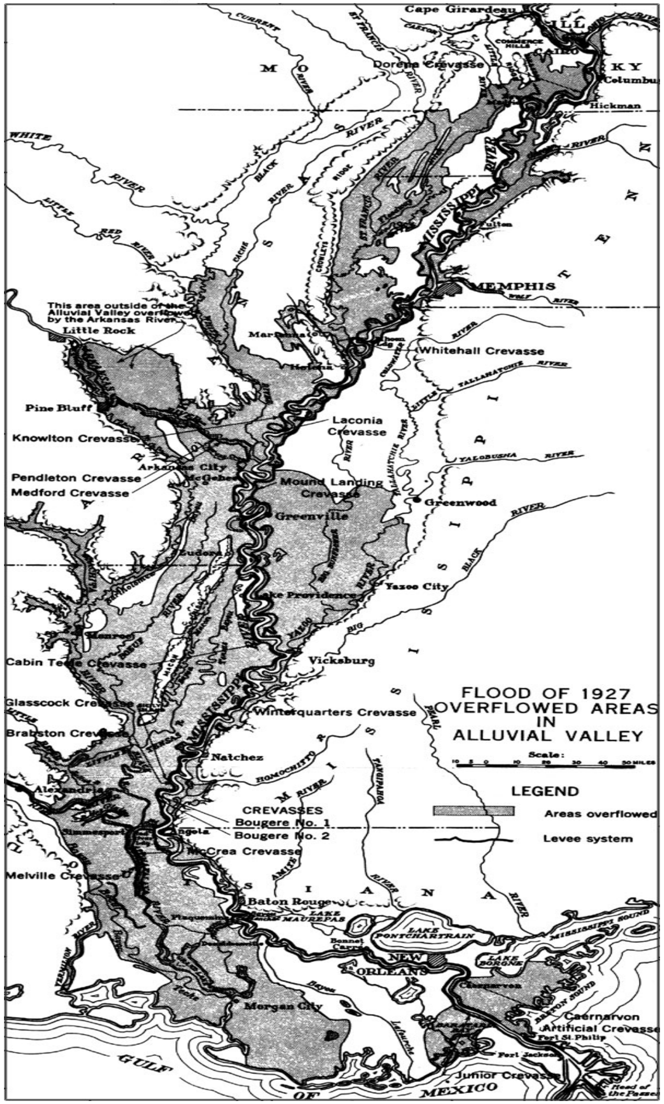
The GREAT 1927 FLOOD

- Greatest flood of the lower Mississippi River Valley on record
- Flooded 27,000 square miles
- Displaced 1,000,000 people, including 325,000 African Americans
- 1st time levees built to the MRC standards failed
- Triggered massive flood control legislation

Areas inundated during the Great 1927 Flood.



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FLOOD OF 1927
• 16.6 Million Acres Flooded
• 162,000 Homes inundated
• $102.6 Million in Crop Losses
• 325,000 Refugees
• 500 People Killed

Tying the ends of a levee to prevent further collapse.

Arkansas City, Arkansas, during the 1927 flood. Inset: Young flood victims find shelter and a meal at a Red Cross refuge camp.

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Floodwaters breach a levee near Grand Tower, Illinois, during the 1927 flood. *National Photo Company Collection (Library of Congress)*

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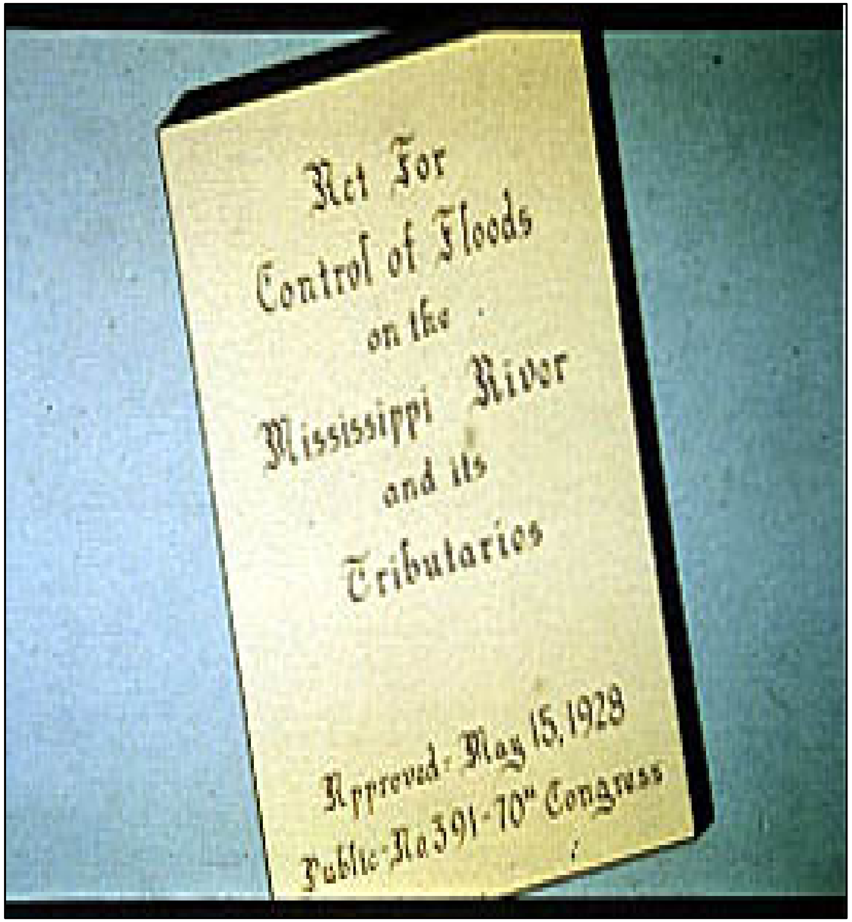
1928 Federal Flood Control Act

- 1928 Flood Control Act (Mississippi Rivers and Tributaries)
- The Jadwin Plan called for improved levee grades and sections
- The concept of floodways was adopted
- Access roads would be made to inaccessible portions of the levees
- Railroad and highway crossings would be made when necessary
- Project flood developed by MRC and U.S. Weather Bureau



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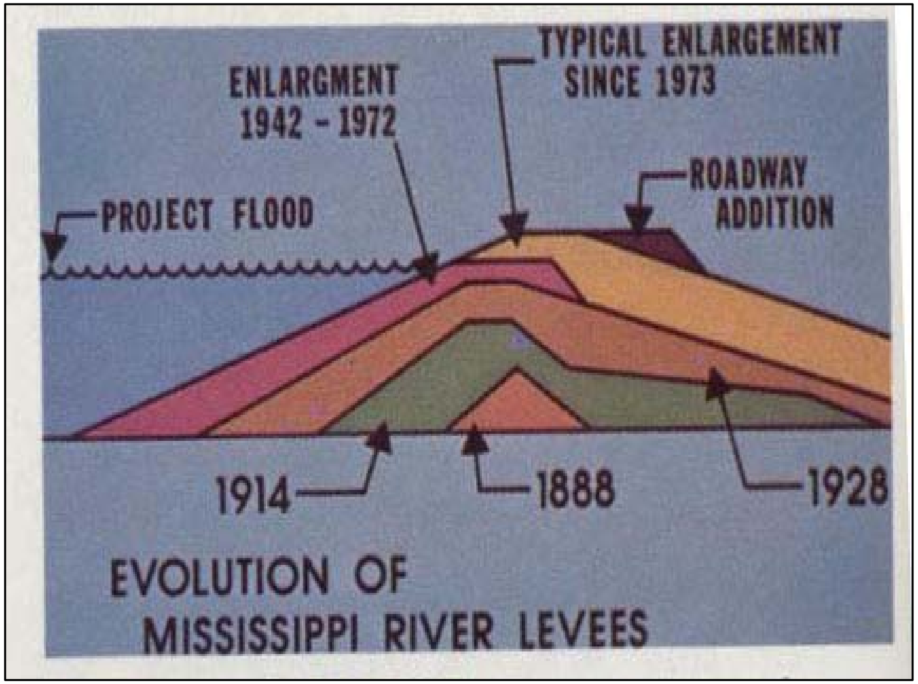
New Levee Standards Adopted

- Freeboard 1 foot above the project flood
- Reverted back to the trapezoidal design
- Riverside slope 1:3 – 1:5; Landside slope 1:6 – 1:8
- Borrow pits are to be located on the riverside as opposed to past locations on the landside
- Levee design life increased from 20 years to 30 years based on levee location



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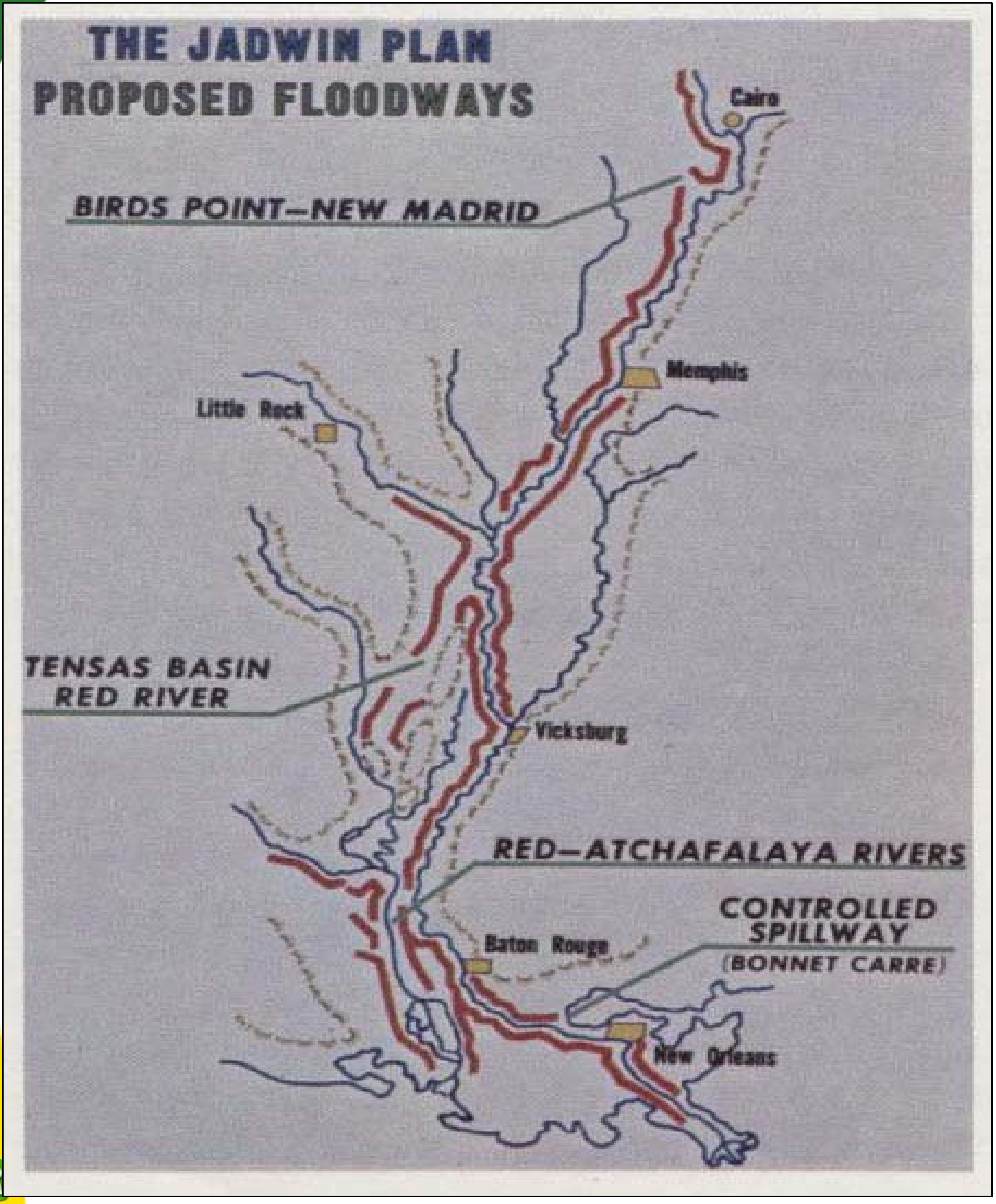

Edgar Jadwin

Major General Edgar Jadwin was Chief of the Corps of Engineers in 1928, so the Corps' plan was named after him

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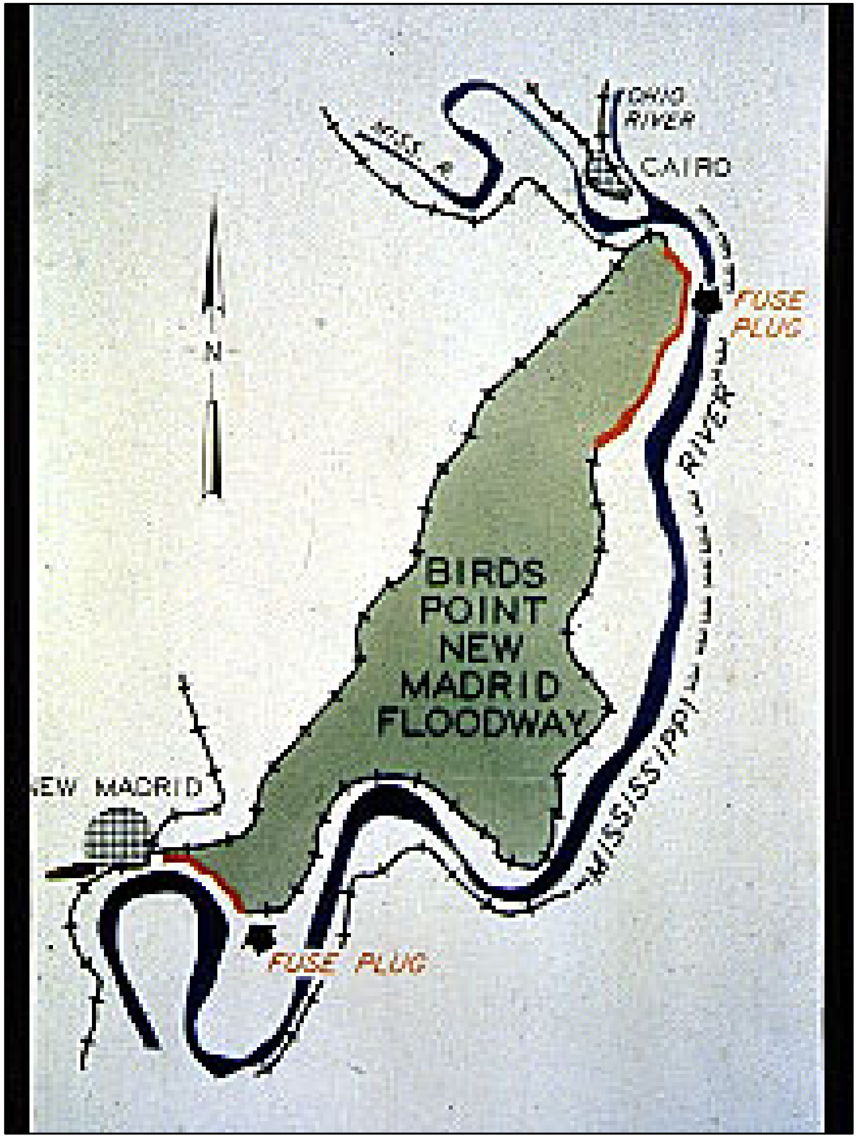
The 1928 Plan Created Vast Floodways

- The passage of excess flows past critical reaches of the Mississippi River through diverted zones
- Floodways along the Mississippi:
  - Birds Point-New Madrid Floodway
  - Morganza Floodway
  - West Atchafalaya Floodway
  - Bonnet Carre Floodway (spillway)

Birds Point-New Madrid Floodway

- The floodway varies in width from 3 to 10 miles, has a length of about 35 miles and includes an area of 210 square miles. It is designed to divert 550,000 CFS from the Mississippi River during the project flood
- Fuse plug levee (almost used in 1993)



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Fuse Plug Levee

- The Fuse Plug Levee is lower than the adjacent levees. If the river rises to high, then water begins to flow over the fuse plug levee rather than over adjacent levees where it would flood human habitations.
- Once water begins to flow over the top of the Fuse Plug Levee, it quickly tears it down until it carries a designated maximum flow rate.
- This is designed to work on its own, but if extremely critical, it can be dynamited.

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Morganza and West Atchafalaya Floodways

- The Atchafalaya River, Morganza Floodway, and West Atchafalaya Floodway converge at the lower end of the Atchafalaya River levees to form the Atchafalaya Basin Floodway
- This system is designed to carry half the Project Flood discharge of 1,500,000 cfs

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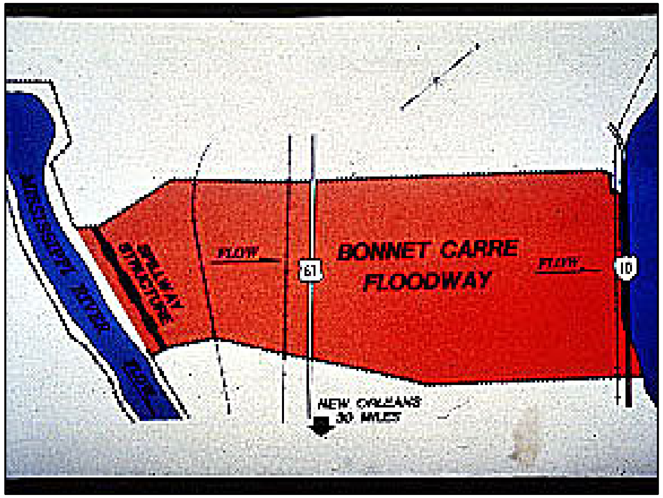
Bonnet Carre Floodway

- The structure is about 7,000 feet long and the floodway extends about 5.7 miles from the river to Lake Pontchartrain.
- It has a design capacity of 250,000 cfs. During the Project Flood, it is operated to restrict the flow in the Mississippi River downstream of the floodway from exceeding 1,250,000 cfs, protecting New Orleans.



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St. Louis Levee in 1928

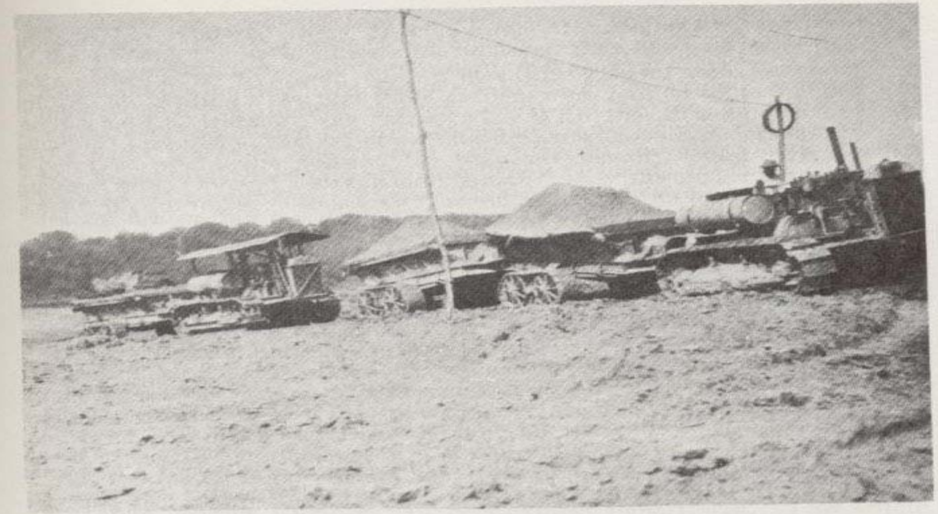
1929 Mississippi River Flood

Protecting the riverside slope of a levee during the 1929 flood.

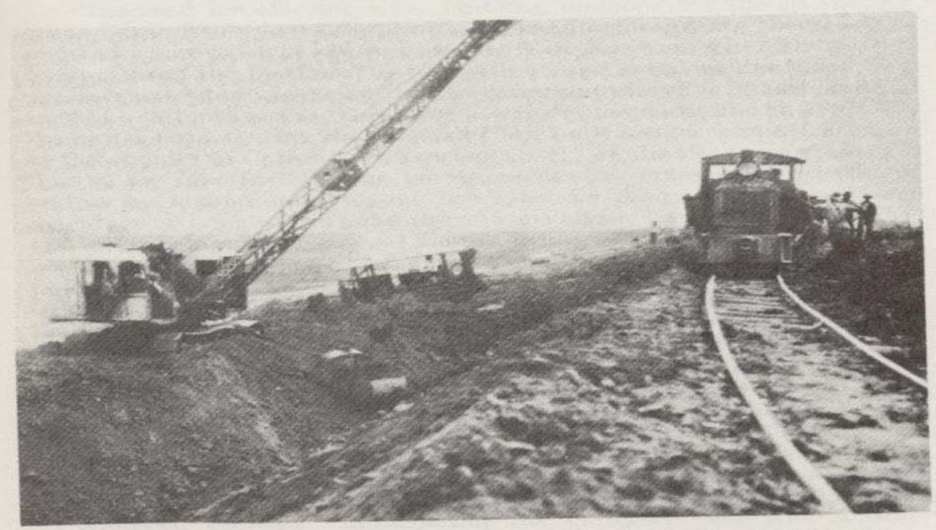
Earth Placement Methods

- Earth placement methods continued to evolve in the 1920s and 30s, lowering unit costs
- Economic haul limit had been 150 feet; with only 5-40 cubic bank yards per team per day per team
- This was improved significantly

LEVEE CONSTRUCTION BY HAUL IN EQUIPMENT



Refuge Setback 12 miles below Greenville, Mississippi.
Tractors and 7-yard wagons placing material.
August 30, 1931.



Greenville Front Enlargement, Greenville, Mississippi. Gasoline locomotive unloading 10 cars of 4 cubic yards each on top of old levee. Shaping up by dragline and tractor bulldozer. August 25, 1931.

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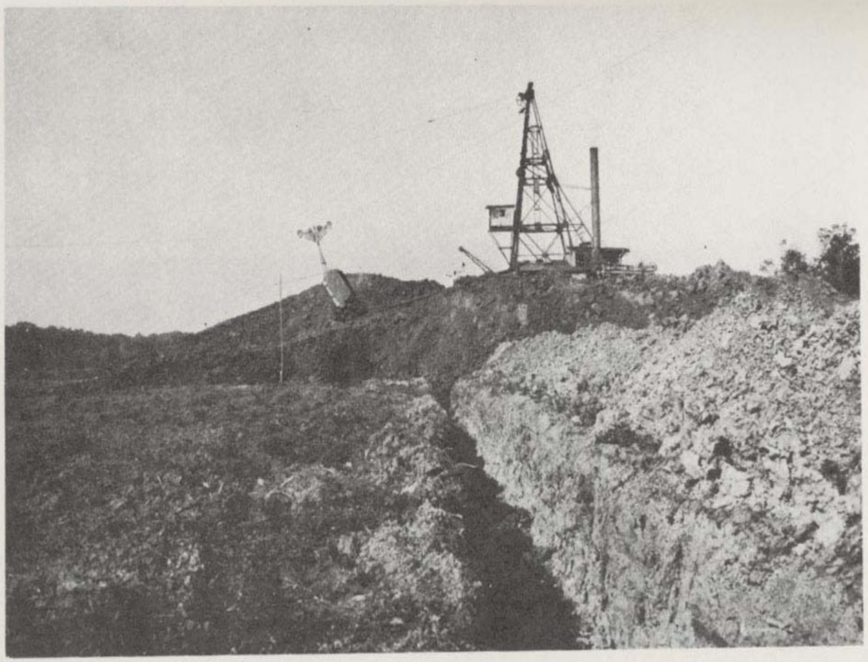
Improved Towers with Draglines

- Draglines employed 3.5 to 10 cubic yard buckets
- Handled 150 to 250 cubic yards per hour
- Haul limit increased to ¼ mile

LEVEE CONSTRUCTION BY DRAGLINE
Morrison-Picayuneville Levee about 25 miles below New Orleans.
June 15, 1931

Front Tail Dragline Towers were employed to construct most of the modern levees as part of the MRT project



LEVEE CONSTRUCTION BY TOWER MACHINE
Bedford-Bayou Vidal Levee 6 miles below Vicksburg. Bucket dumping in levee section. Tailtower and borrow pit not shown. October 10, 1931.

LEVEE CONSTRUCTION BY TOWER MACHINE
Cottage Bend near St. Joseph, Louisiana. View from levee section showing riverside borrow pit and tail tower. Mississippi River shown in background. February 26, 1931.

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Levee Comparisons

- **Length of levee system below Cape Girardeau**

Year	Miles
1880	991
1890	1,239
1910	1,500
1923	1,555
1927	1,582
1931	1,830

TABLE XXXIII

COMPARISON OF LEVEE GRADES RECOMMENDED BY HUMPHREYS AND ABBOT (1861), AND THE LEVEE COMMISSION (1875), WITH THOSE ADOPTED IN 1928

(Expressed in feet and referred to zeros of present gages at stations listed)

Locality	Miles below Cairo	Grade Line Recommended by Humphreys and Abbot, 1861	Grade Line Recommended by Levee Commission, 1875	1928 Grade Line
Cairo	0	53.6	53.6	60.0
Columbus	21.8	46.7	46.7	54.0
New Madrid	71.0	38.8	38.8	52.5
Cottonwood Point	124.5	42.9	42.9	49.5
Fulton	175.4	40.9	40.9	50.5
Memphis	227.0	40.0	40.0	54.5
Mhoon Landing	273.2	45.5	45.5	53.0
Helena	307.1	50.6	50.6	66.5
Sunflower Landing	353.7	50.6	50.6	61.0
Mouth of White River	391.7	55.2	55.2	65.0
Arkansas City	436.7	54.0	54.0	63.5
Greenville	480.2	50.3	50.3	59.5
Lake Providence	542.0	51.3	51.3	57.5
Vicksburg	601.8	51.5	51.5	61.0
St. Joseph	662.4	47.8	47.8	58.0
Natchez	705.7	52.4	52.4	61.0
Red River Landing	772.6	50.3	51.3	60.5
Bayou Sara	806.9	41.4	43.4	54.0
Baton Rouge	841.0	38.2	39.2	50.0
Plaquemine	861.0	33.3	35.3	44.5
Donaldsonville	892.8	29.9	31.9	39.0
College Point	911.3	25.3	27.2	34.5
Carrollton	964.5	18.5	20.2	25.2

COST COMPARISONS

TABLE XXXIV

Unit Costs of Levee Construction 1860 to 1931

	Cost per Cubic Yard
Estimate contained in report of Delta Survey, 1861	20 cents
Estimate contained in report of Gen. A. A. Humphreys, 1865	40 cents
Estimate of the Levee Commission, 1875	40 cents to 43 cents
Unit cost of levee construction under jurisdiction of the Mississippi River Commission—from organization of the Commission to June 30, 1928	approximately 23 cents*
Cost of levee construction under jurisdiction of Mississippi River Commission—July 1, 1928 to December 31, 1931	24.5 cents*

* Including overhead.

TABLE XXXVI

Cost Ratios of Different Methods of Present Day Levee Construction
(as compared with average cost)

Method	Cost Ratio
Haul-in	1.229
Dragline	.865
Tower and dragline	.871
Tower	.978
Hydraulic	1.22[illegible]
Average	1.000

TABLE XXXV

Average Unit Costs of Levee Construction by United States
Since Passage of Act of May 15, 1928
(July 1, 1928 to Dec. 31, 1931)

Fiscal Year	Cost per Cubic Yard
1929	31.7 cents
1930	26.7 cents
1931	24.8 cents
1932 (first half of year)	19.8 cents

Total Yardage—201,085,000 Cubic Yards.
Average Cost per Yard for Period July 1, 1928 to Dec. 31, 1931 - 24.5 cents.

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1937 Flood Emanated from the Ohio River watershed

Raising the level of protection at Cairo during the 1937 flood.

The Birds Point-New Madrid Fuse Plug Levee was used in 1937

Blasting the fuseplug levee at the Birds Point-New Madrid Flood on January 25, 1937.

Floodway Concept Demonstrated

The Birds Point-New Madrid Floodway in full operation.

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Roads Added to Levees

- Before 1938, the MRC discouraged any motorized travel on the levees as dangerous because the weight would contribute to the 'sinking of the levees'
- The flood fight of 1937 had been hampered by the difficulty of transporting materials to critical areas. As a result, in 1938, the MRC passed a resolution directing the various districts to begin the construction of gravel roads on the levee crowns.

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Changes in Levee Design ~ 1947

- **The MRC recognized the value of soil compaction in 1947 resulting in the *Code for Utilization of Soils Data for Levees***
- **It was based around 3 sections:**
  - **Type 1**
  - **Type 2**
  - **Type 3**

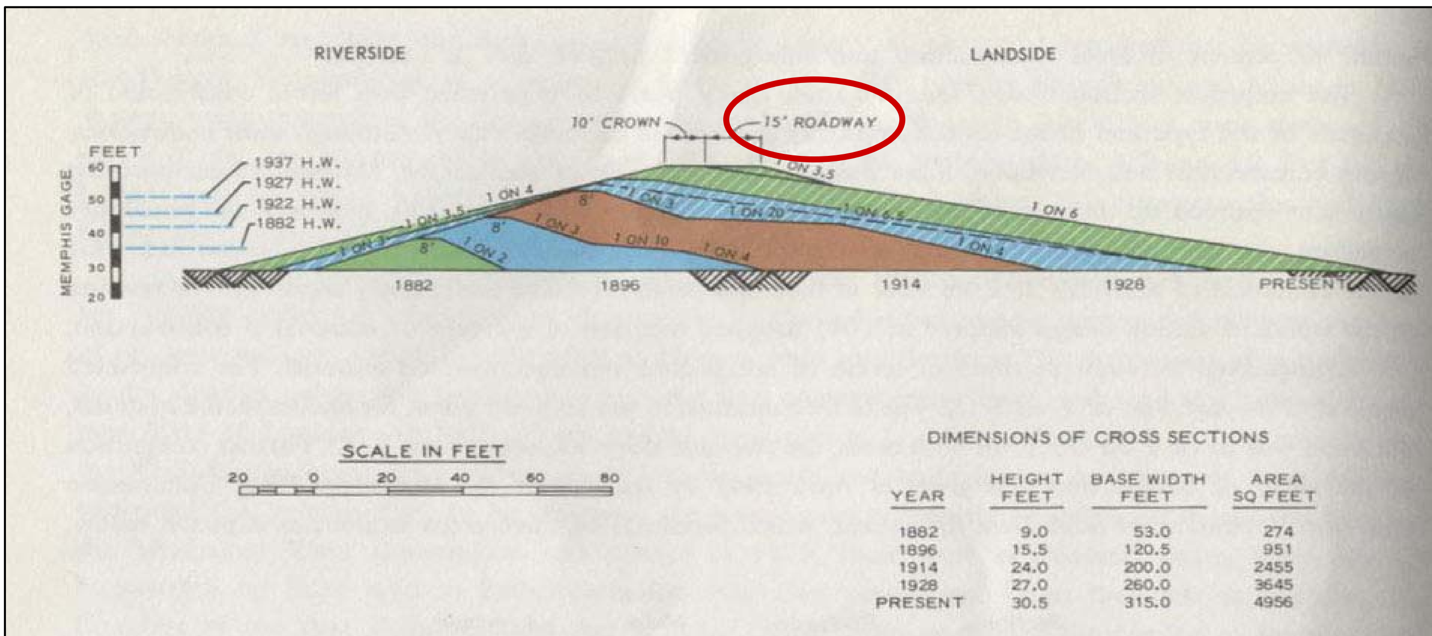

Figure 25. Evolution of the standard levee section, 1882 to 1972

Soil Compaction Mandated

- Type 1 (5% shrinkage)
  - New levee construction
  - Control of moisture content
  - Compaction in layers by sheepsfoot
- Type 2 (10% shrinkage)
  - New levee construction
  - Maximum practicable compaction (moderate compaction) of wet soils at least cost
- Type 3 (15% shrinkage)
  - New/emergency levee construction
  - No compaction required

Section Type	*Riverside Slope*	*Crown Width feet*	*Landside Slope*
1	1 on 3-1/2	10	1 on 4-1/2
2*	1 on 4	10	1 on 5-1/2
2**	1 on 4	10	1 on 6
3	1 on 4-1/2	10	1 on 6-1/2

* Less than 25 feet in height.
** Twenty-five feet or more in height.

Project Design Flood, 1956-1958

- The project flood storm series developed by the National Weather Service is made up of three historic storms
- Intended to predict the largest Mississippi River flood that can reasonably be expected to occur
- The total peak flow of the Mississippi and Atchafalaya Rivers during this flood is about 3,000,000 cfs at the latitude of Red River landing

How the Project Flood was compiled

- **The January 1937 storm is assumed to occur, increasing the volume by 10 percent over the Ohio and Lower Mississippi River Basins.**

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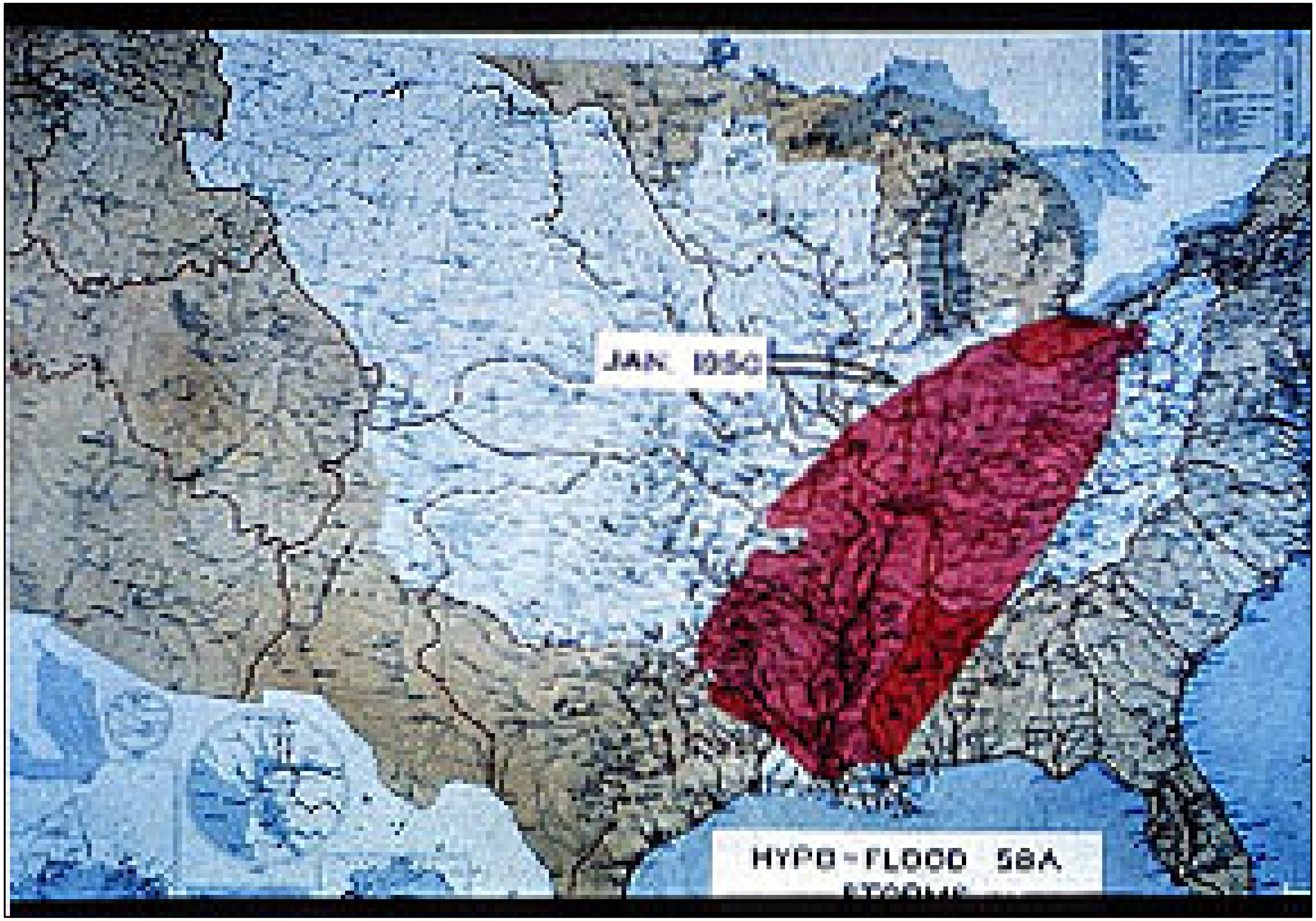
Compiling the Project Flood - continued

- **It is followed in 4 days by the January 1950 storm over the same general area**

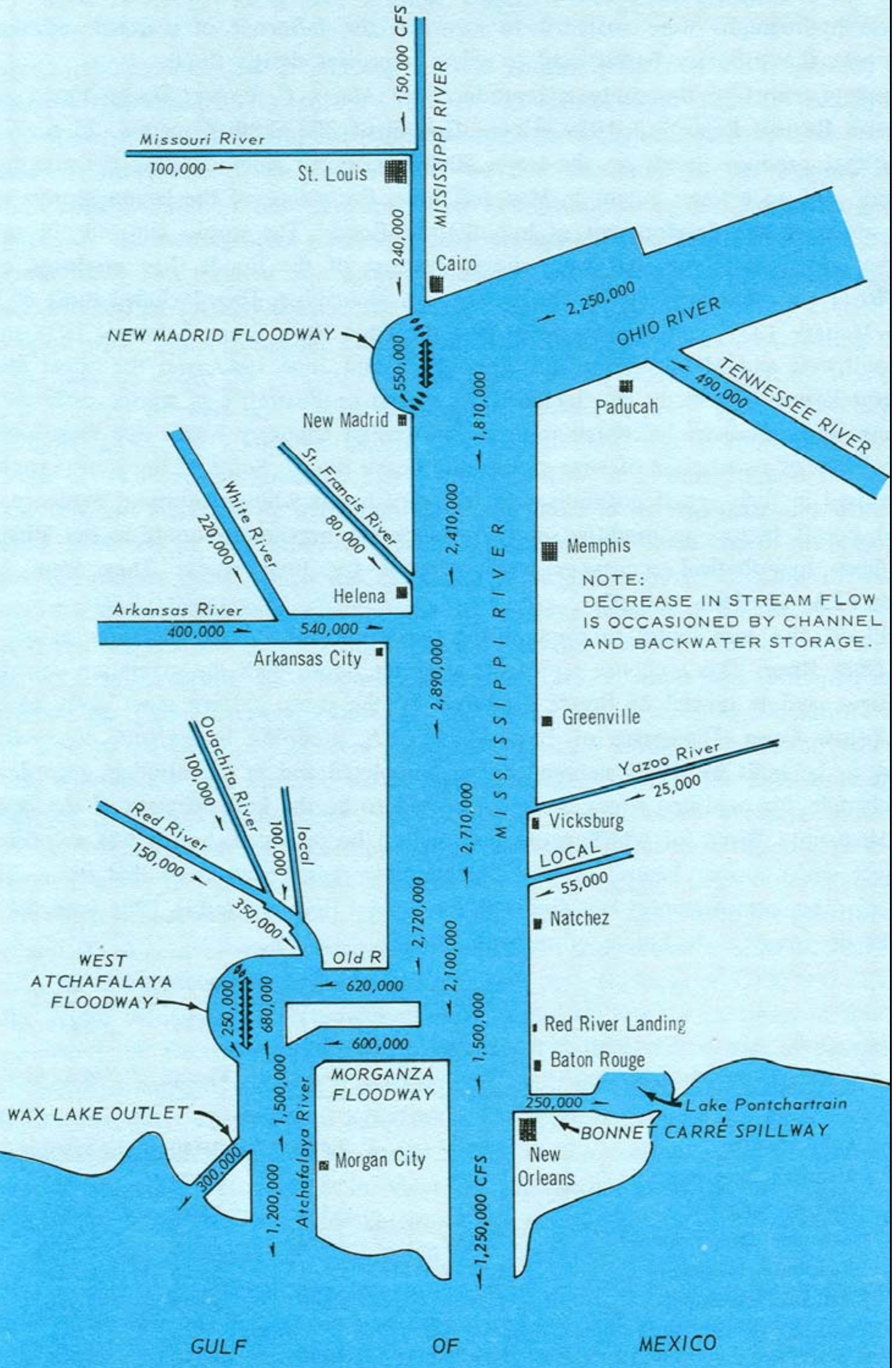


Third Assumed Storm in Project Flood

- **Three days later, the February 1938 storm was placed over all the tributary basins of the lower Mississippi River**

Final Project Flood

MRC’s Project Design Flood for the Lower Mississippi Valley



Levee Evolution Between St. Louis and Cape Girardeau

- The project design flood was designed for levees south of Cape Girardeau
- The St. Louis District, COE built the levees between St. Louis and Cape Girardeau based on 3 floods:
  - Flood of 1844 for urban levees and 50-year flood for agricultural levees
  - Flood of 1973, updated profile in 1979
  - Flood of 1993, updated profile in 2003
- Present practice is to build levees based on economic optimization in conjunction with the 2003 profiles

St. Louis District Engineer
Claude Norman Strauser

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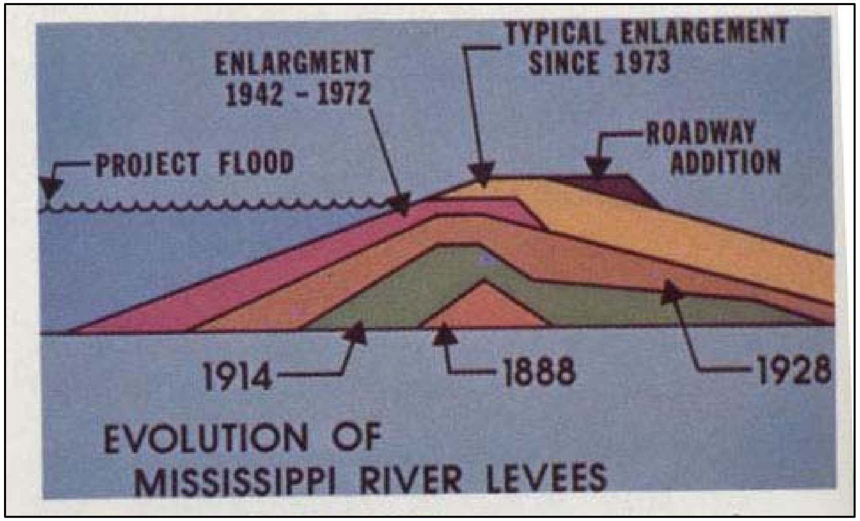
1973 Mississippi River Flood

- **The flood of 1973 caused damages estimated at $183,756,000 and set a record for days-out-of-bank at 62**
- **The flood of 1973 brought about the realization that the carrying capacity of the river had decreased; meaning the flow of water would now be at a higher elevation, meaning levees would need be raised once again**

DOWN TOWN ST. MARYS DURING THE FLOOD OF 1973



Levee vs. No Levee

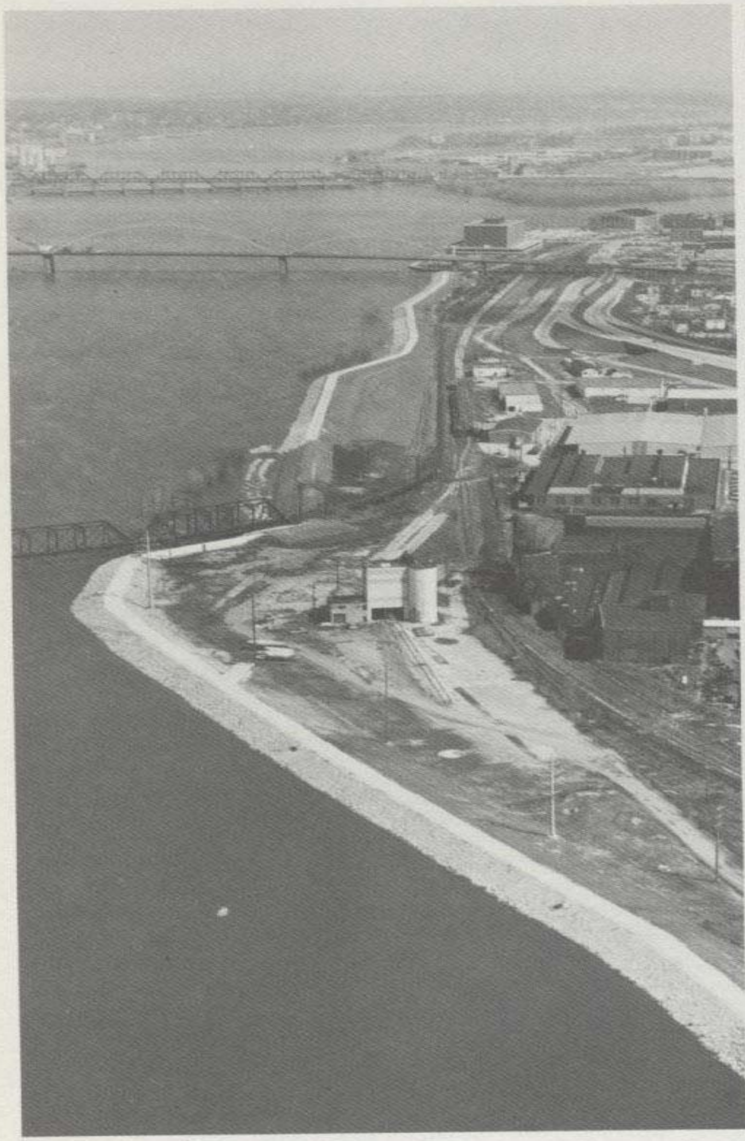


FIG. 72. The newly completed Rock Island levee kept Rock Island dry during the 1973 flood.

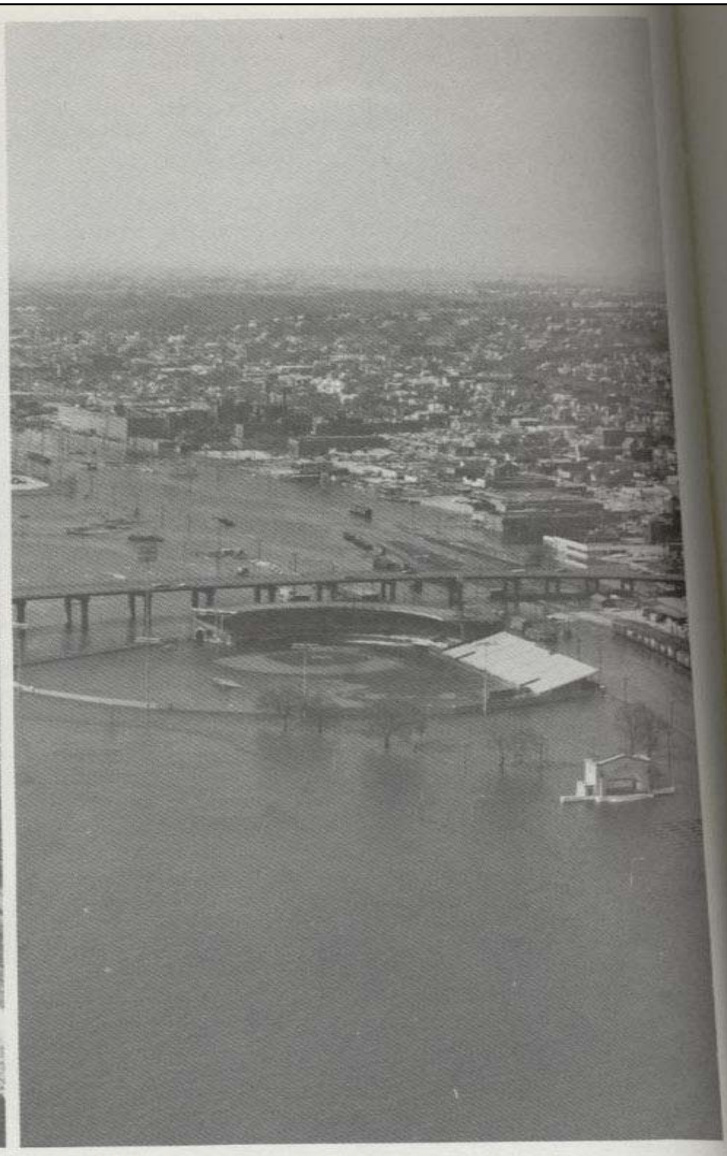
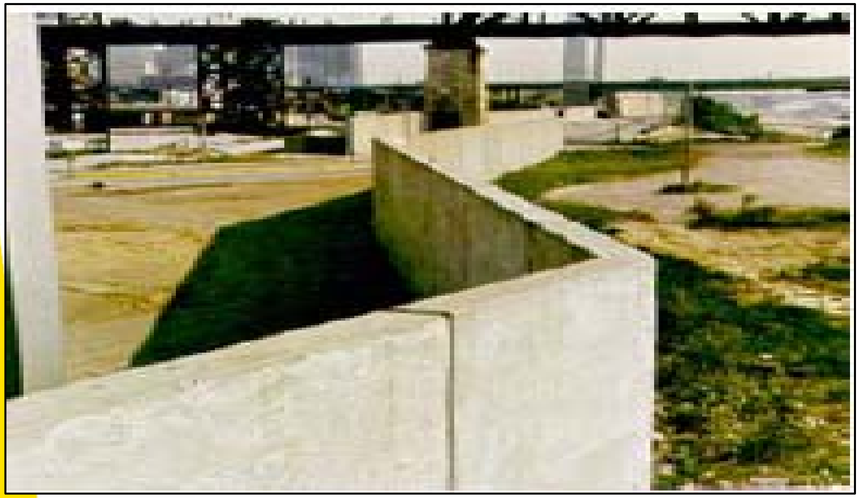
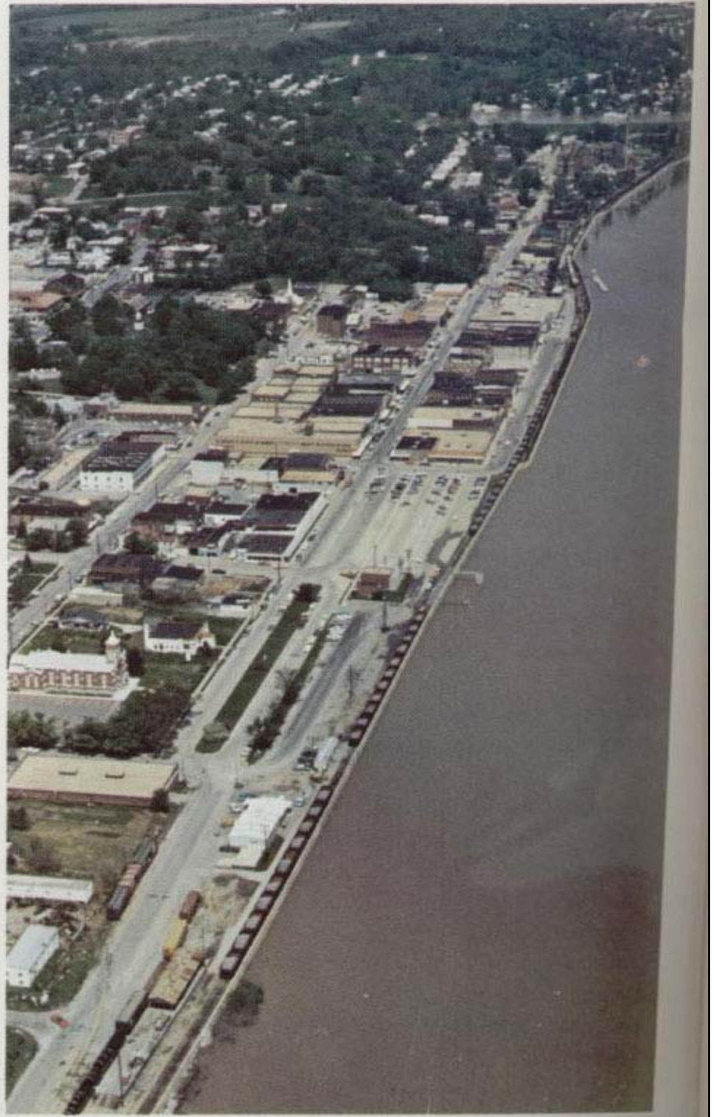


FIG. 73. Davenport, Iowa, just across the river from Rock Island, during the 1973 flood, with a flood control project still in the talking stage.

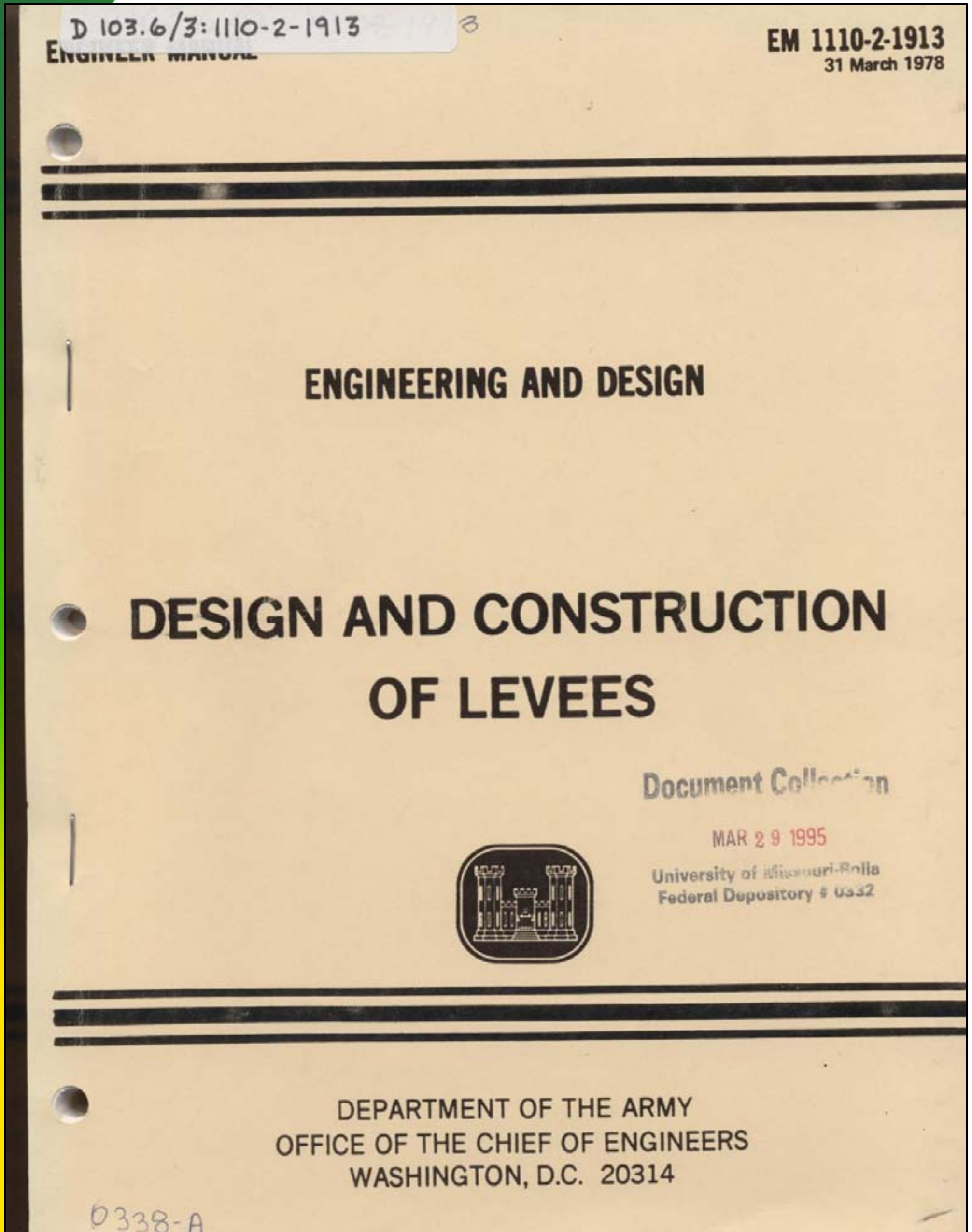
Floodwall protection

- **Floodwalls are used in urban areas where there is little land available for the construction levees**





The Cape Girardeau Flood Protection Project proved its worth in the 1973 flood.



ENGINEER MANUAL

EM 1110-2-1913
31 March 1978

ENGINEERING AND DESIGN

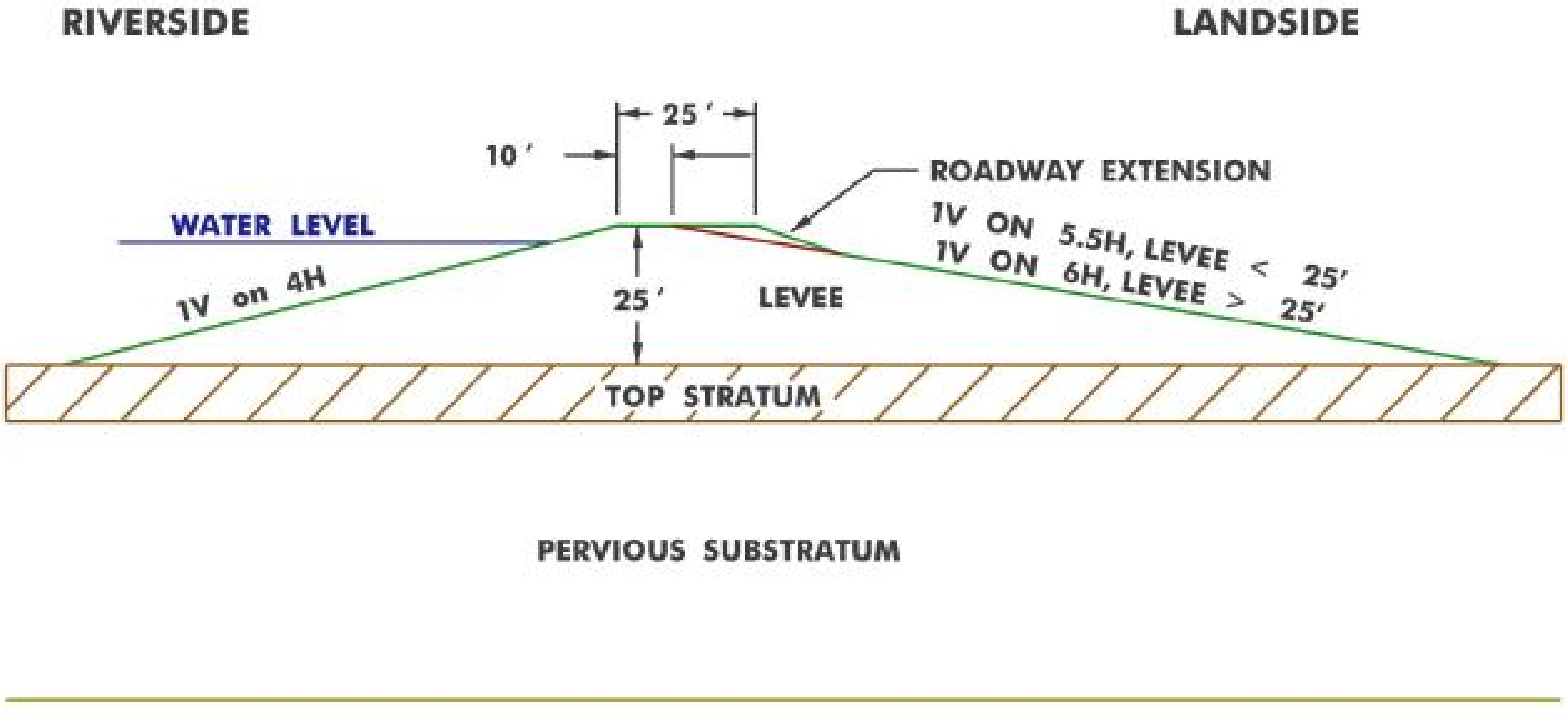
DESIGN AND CONSTRUCTION OF LEVEES

DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON, D.C. 20314

Benchmark Standards for Levee Design and Maintenance 1978 - Present

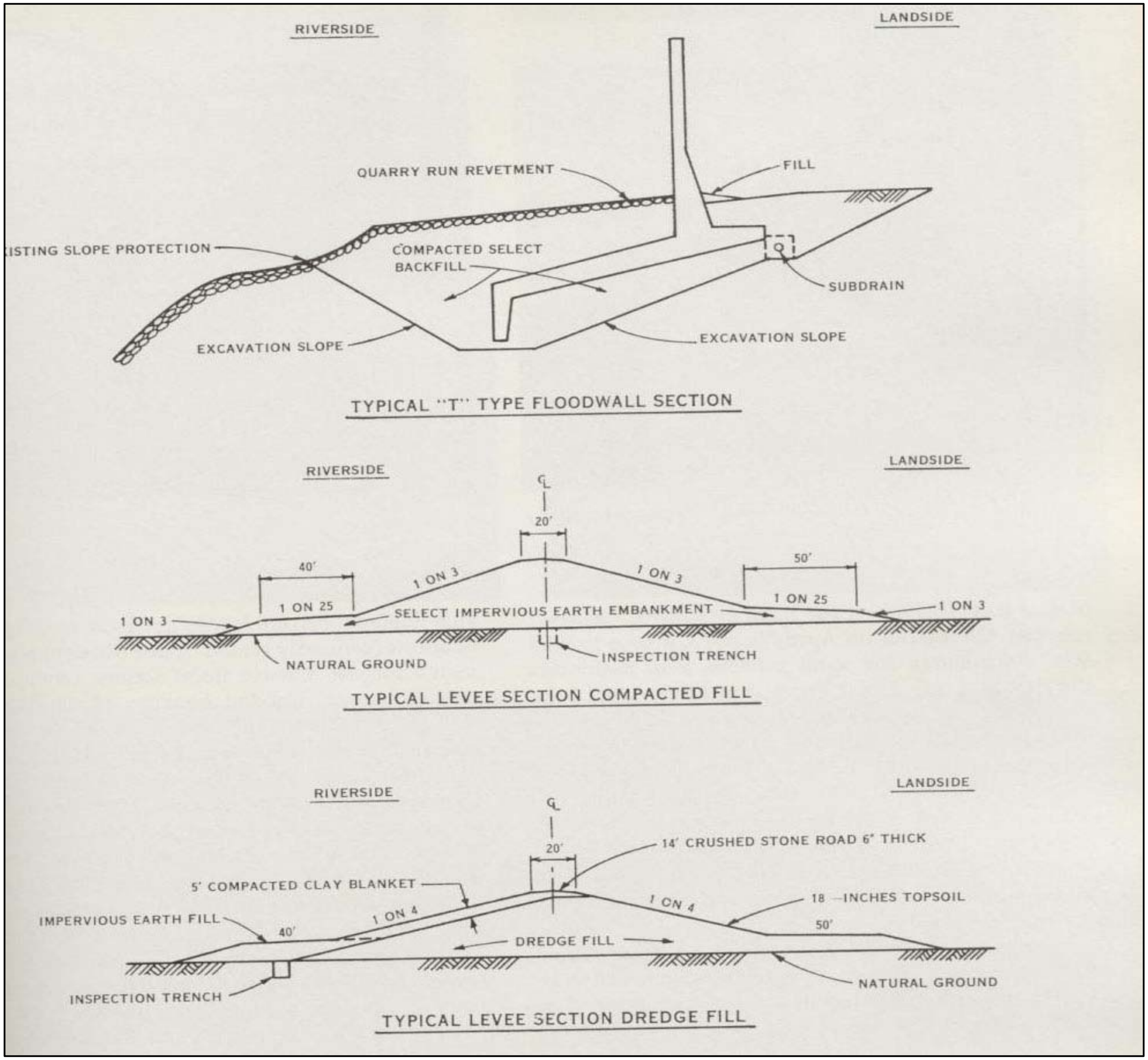
Table 7-1. Classification According to Construction Method of Levees Composed of Impervious and Semipervious Materials

Category	Construction Method	Use
I. Compacted	Specification of: a. Water content range with respect to standard effort optimum water content b. Loose lift thickness c. Compaction equipment (sheepsfoot or rubber-tired rollers) d. Number of passes to attain a given percent compaction based on standard maximum density	Provides embankment section occupying minimum space. Provides strong embankments of low compressibility needed adjacent to concrete structures or forming parts of highway systems. Requires strong foundation of low compressibility and availability of borrow materials with natural water contents reasonably close to specified ranges.
II. Semicompacted	Compaction of fill materials at their natural water content (i.e., no water content control). Placed in thicker lifts than Category I (about 12 in.) and compacted either by controlled movement of hauling and spreading equipment or by fewer passes of sheepsfoot or rubber-tired rollers. Compaction evaluated relative to 15-blow compaction test.	The most common type of levee construction used in reaches where: a. There are no severe space limitations and steep-sloped Category I embankments are not required. b. Relatively weak foundations could not support steep-sloped Category I embankments. c. Underseepage conditions are such as to require wider embankment base than is provided by Category I construction. d. Water content of borrow materials or amount of rainfall during construction season is such as not to justify Category I compaction.
III. Uncompacted	a. Fill cast or dumped in place in thick layers with little or no spreading or compaction. b. Hydraulic fill by dredge, often from channel excavation.	Levees infrequently constructed today using method a except for temporary emergency. Both methods are used for construction of landside and riverside berms. Method b is used in some areas to build the entire levee section. Construction results in very flat slopes, with large space requirements.



TYPICAL MISSISSIPPI RIVER LEVEE SECTION

Typical Levees and Flood Walls



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Construction Methods

Hydraulic Fill Dredge

Hydraulic dredges repairing the damaged Sny levee.

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Earth Levee Enlargements

- **Riverside levee enlargements are the preferred method due to cost and stability**
- **Landside enlargements are the least preferred**

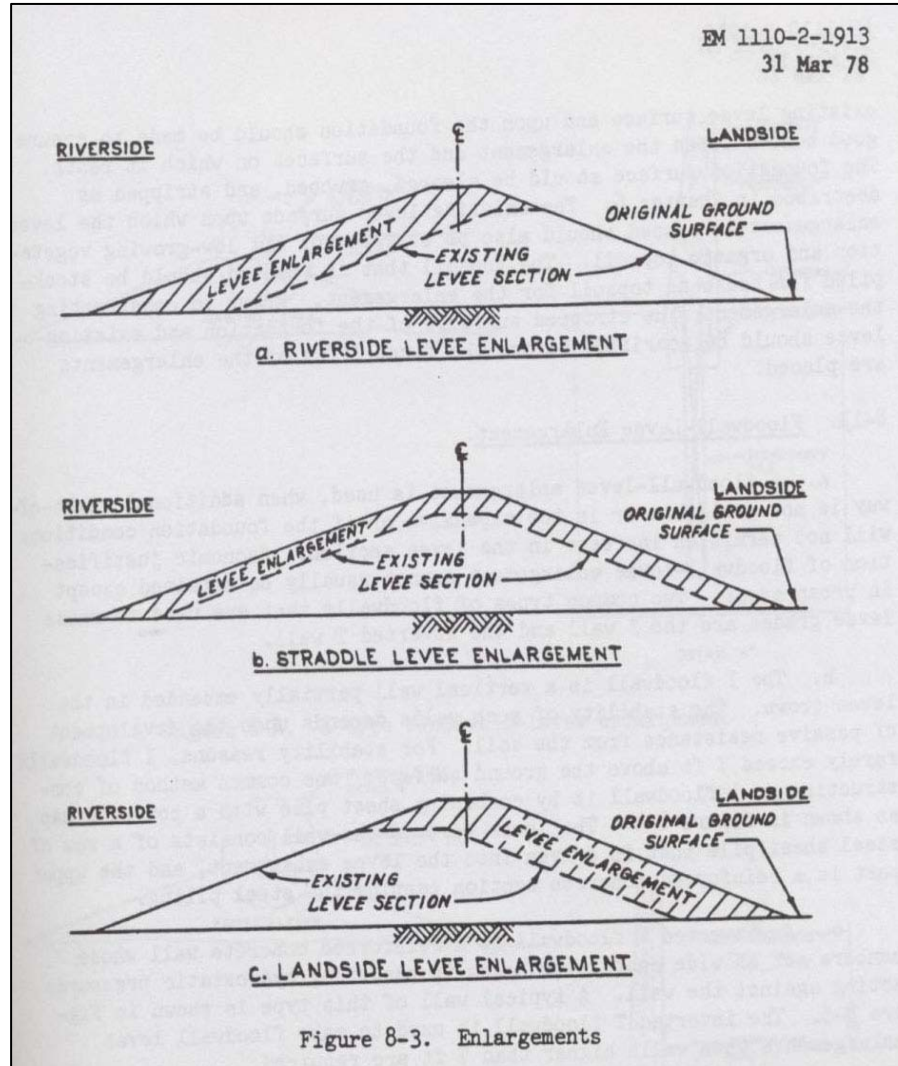


Figure 8-3. Enlargements

Floodwall Levee Enlargement

- The I-wall is rarely used to exceed 7 ft above ground surface; it is made by combining sheet piling with a concrete cap
- The T-wall is used when wall higher then 7 ft are required; it is made from reinforced concrete

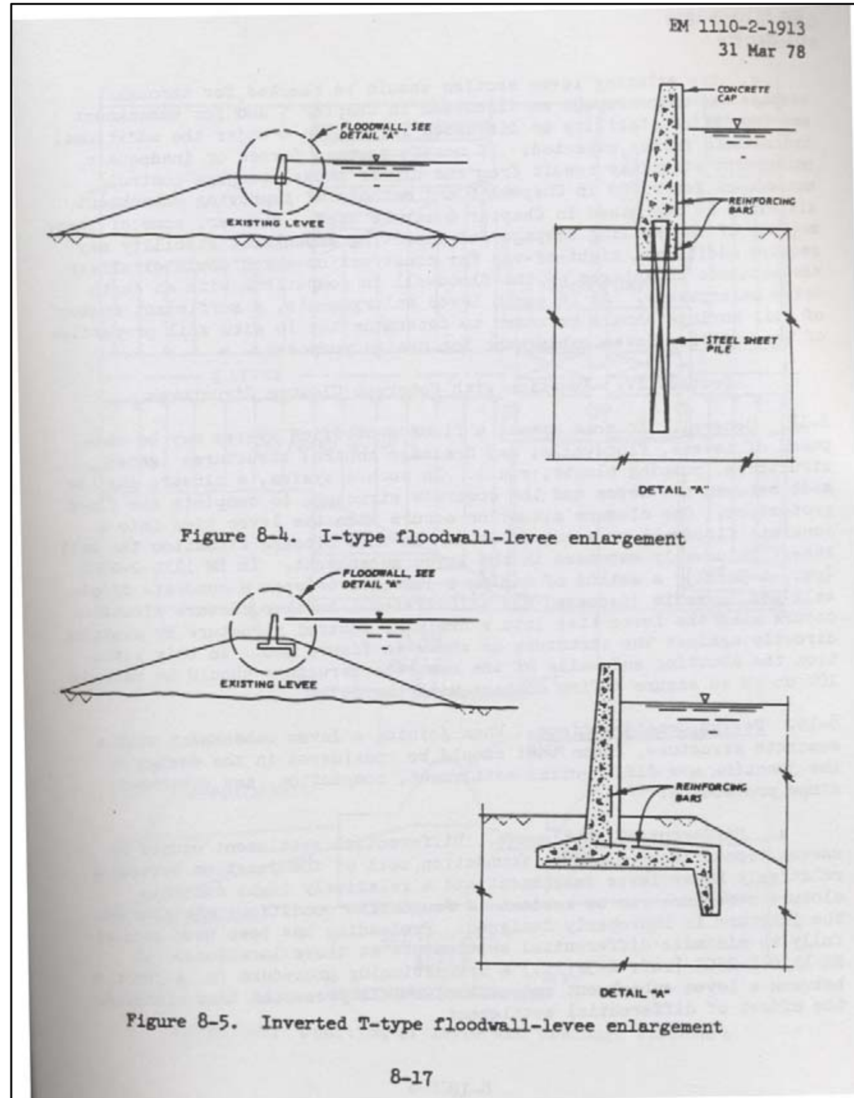


Figure 8-4. I-type floodwall-levee enlargement

Figure 8-5. Inverted T-type floodwall-levee enlargement

8-17

Turnout/Turnaround

- **Turnouts allow for the passing of two vehicles on a one-lane access road on a levee**
- **Turarounds allow for vehicles to reverse their direction when a levee dead-ends without an exit ramp**

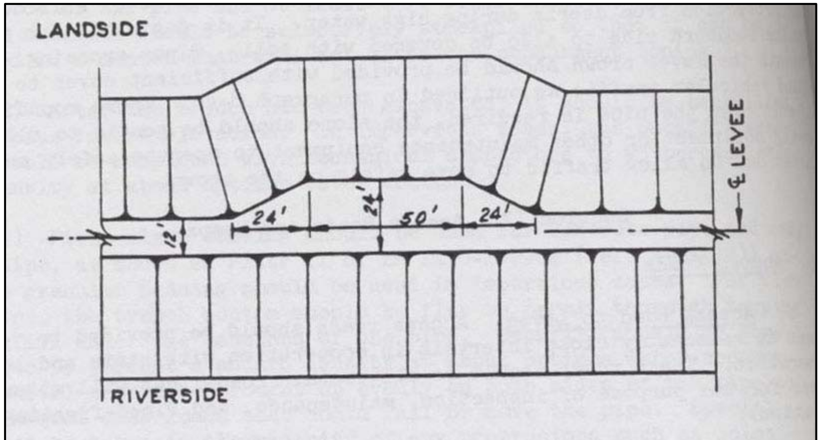


Figure 8-1. Example of levee turnout

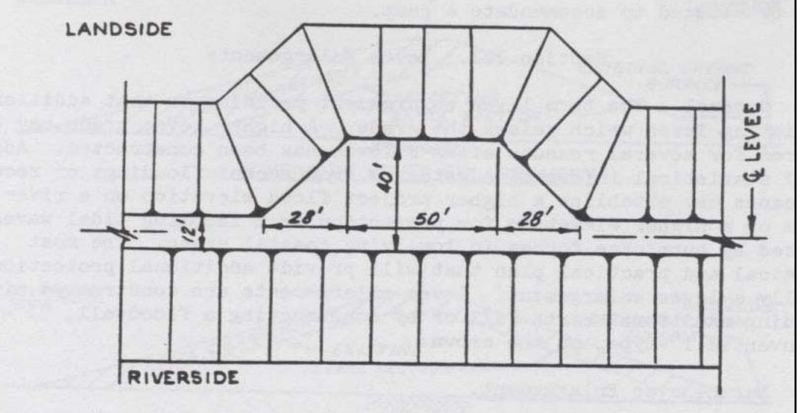


Figure 8-2. Example of levee turnaround

Toe Trenches

- Toe trenches are used to assist in the prevention of shallow underseepage
- Toe trenches are often used with relief wells, the wells collect the deeper seepage

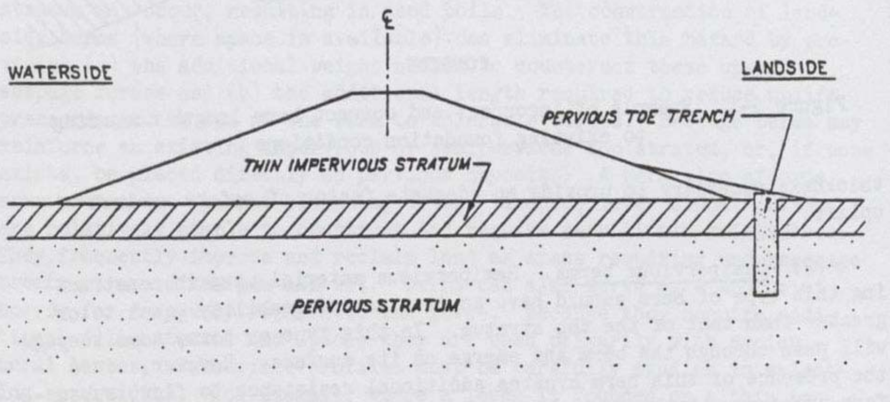


Figure 5-2. Typical partially penetrating pervious toe trench

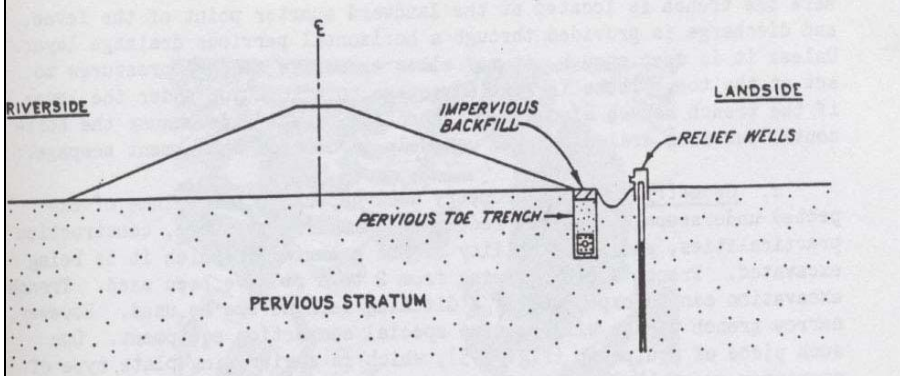
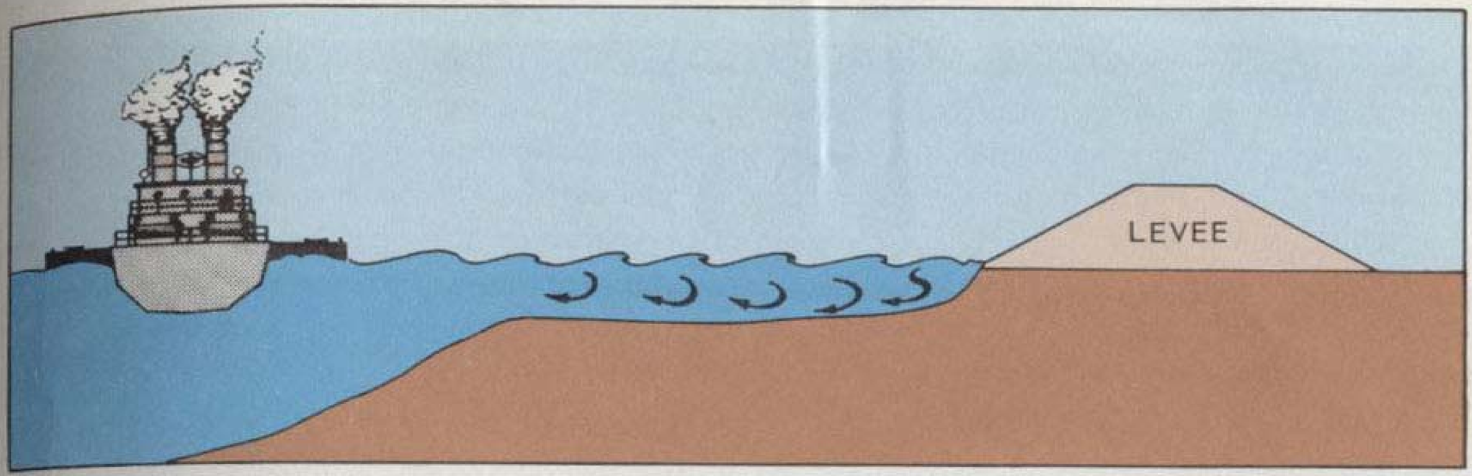


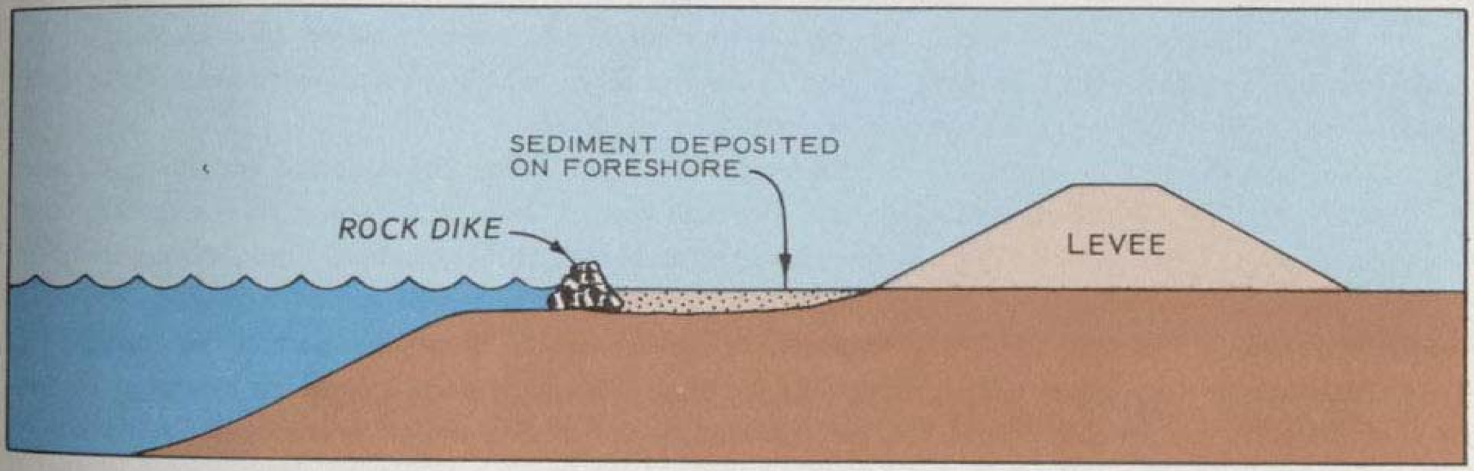
Figure 5-3. Typical pervious toe trench with collector pipe (Figure 5-6 shows trench details)

Collector systems are usually not required for agricultural levees but find wider use in connection with urban levees.

Foreshore Protection



a. Foreshore attack



b. Foreshore protection

Figure 28. Foreshore attack and protection

Junction of Levee and Drainage Structure

- **Considerations when a levee abutts a concrete structure**
  - **Differential settlement**
  - **Compaction of the levee wall**
  - **Slope protection to prevent scouring**

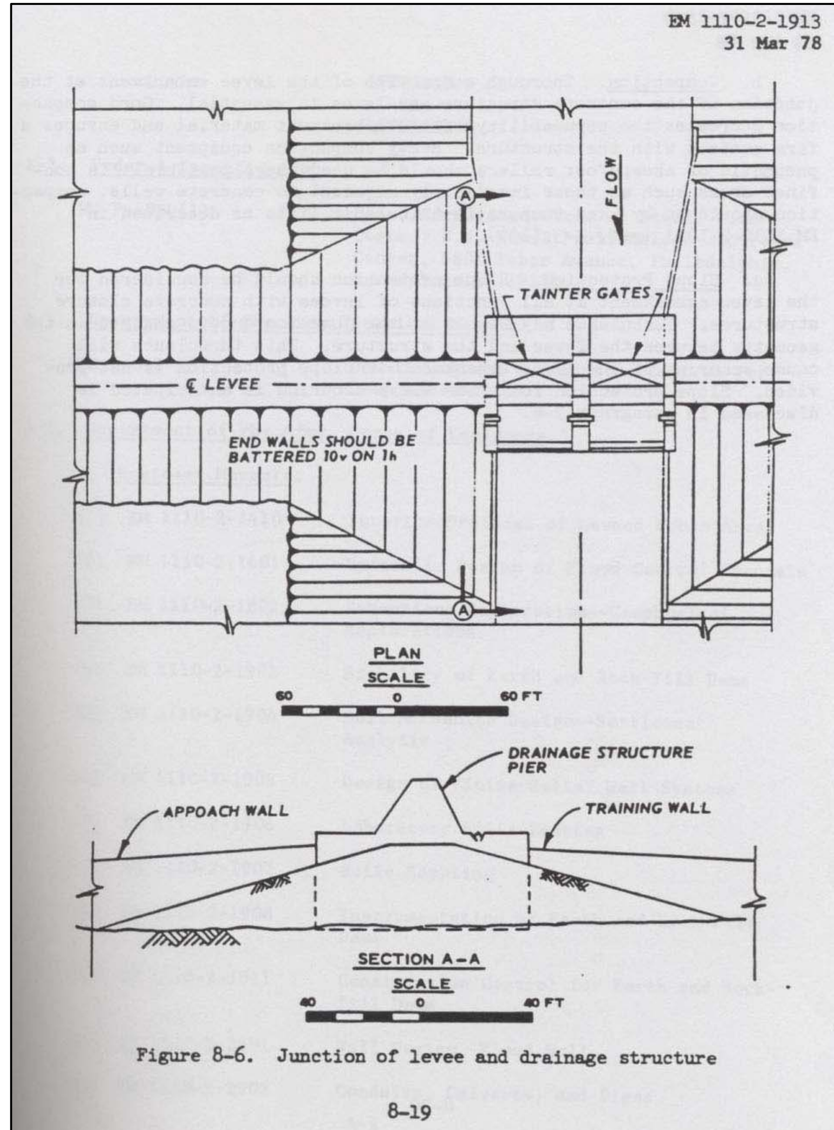


Figure 8-6. Junction of levee and drainage structure

Drainage Structures

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Levees with Public Use

- Levees today are built with roadways on top and some are open to public use
- The COE prefers to construct levees with no adjoining structures (flood gates excluded), but when unavoidable will incorporate them in to the levee system

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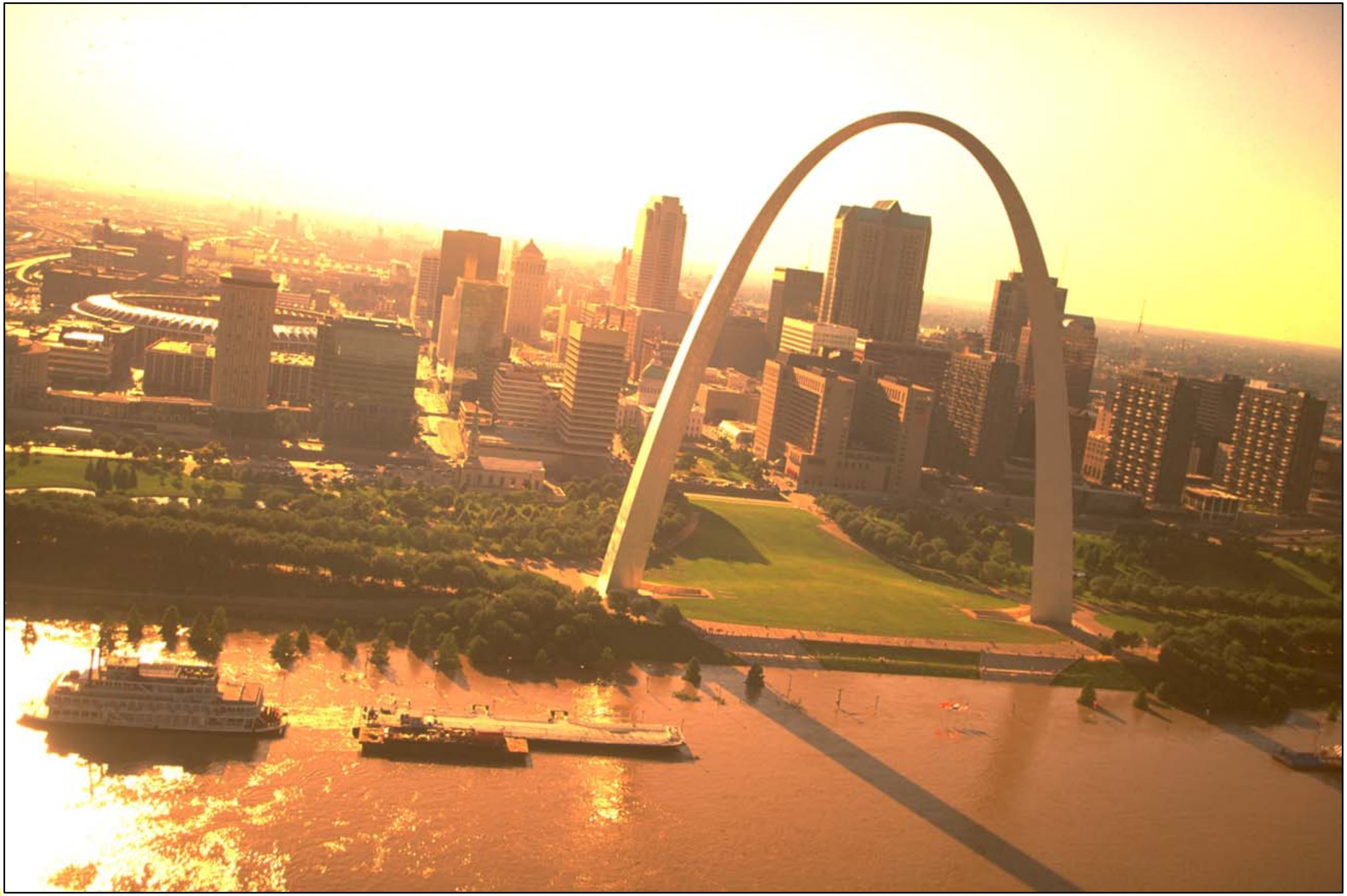
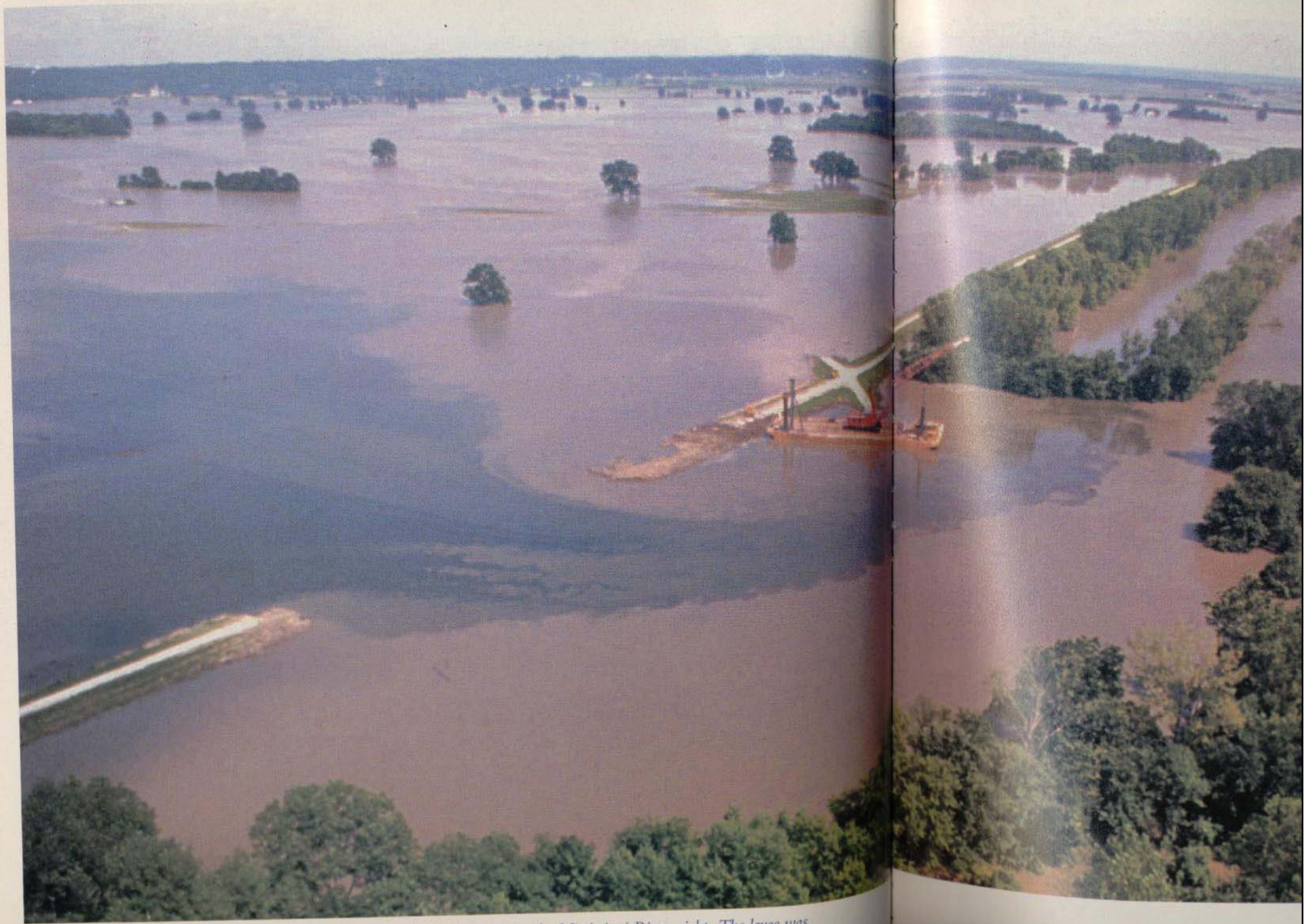
Flood of 1993 –Recent Test of the Levee System



COE Induced Levee Break



Mississippi River floodwaters, shown left of a broken levee, slowly flow back in the Mississippi River, right. The levee was broken by the Corps of Engineers to flood farmland north of Prairie Du Rocher, Illinois, to attempt to stop rushing floodwaters

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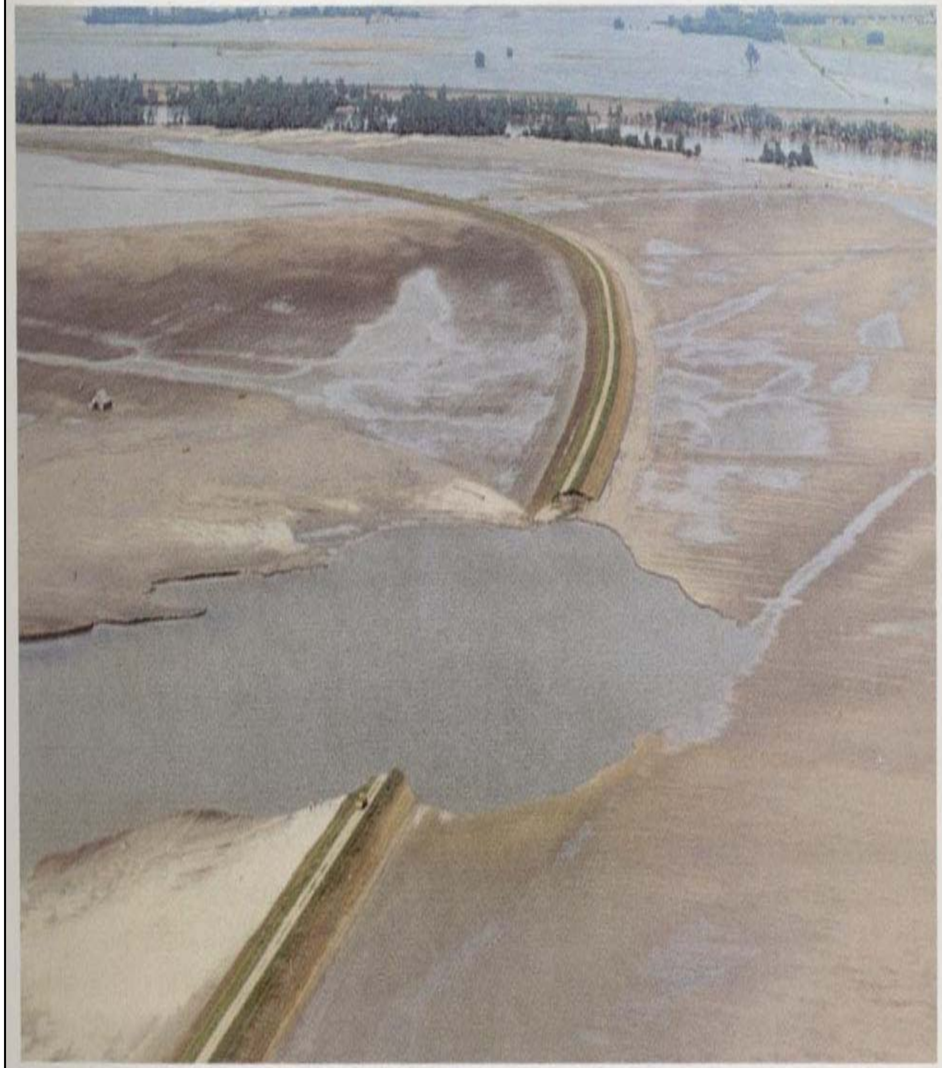
Levee Overtoppings and Crevasses

The Missouri River defeated this levee near Boonville, Missouri.

Nutwood Levee break on the Illinois River.



Levee breach at L470-460 near Elwood, Kan.

1993 Flood Damage

Floodwaters from the Mississippi River cover the river town of Elwood with a blanket of muddy water after a levee north of the community broke.

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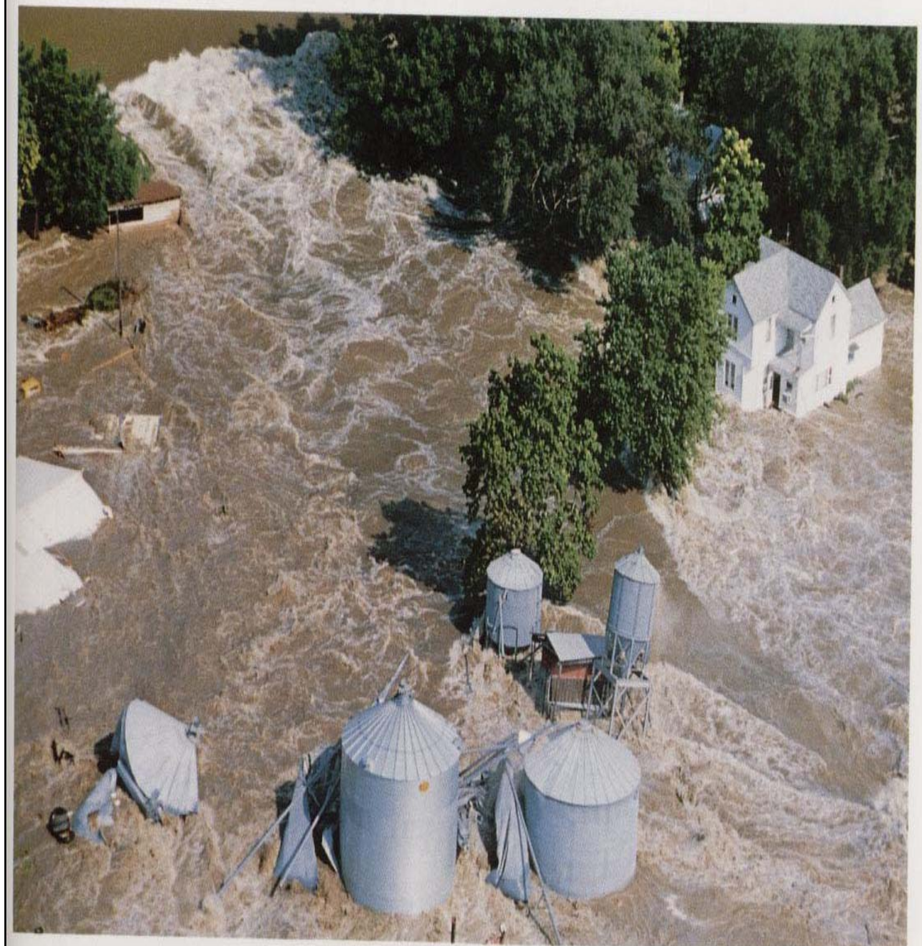

Rushing water from a levee break in Columbia, Illinois, demolished these buildings shortly after the photograph was taken.

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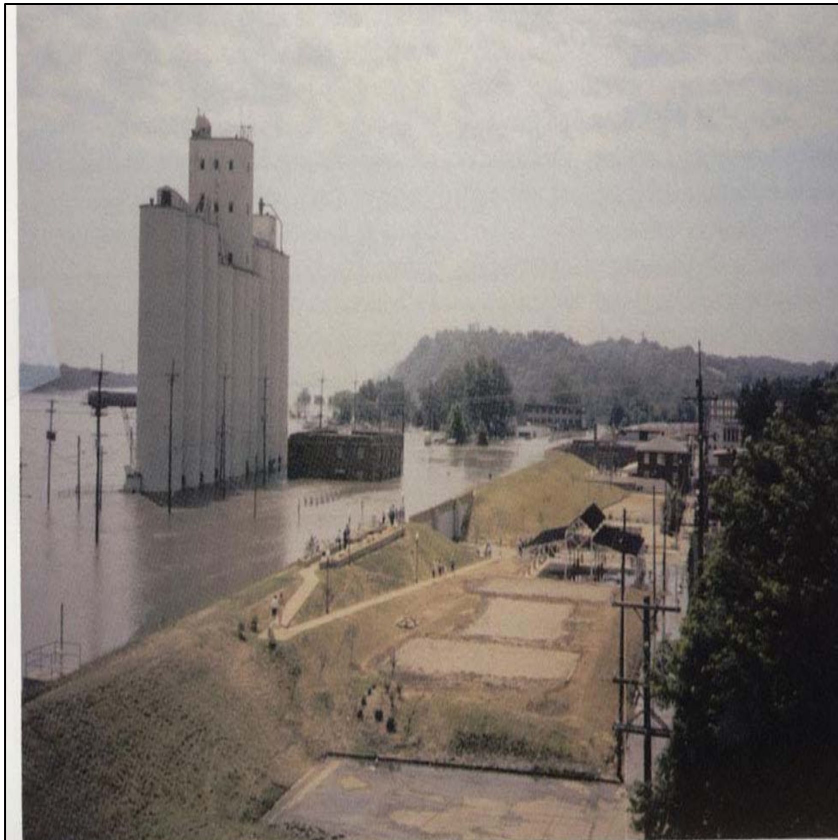
Levee Protection at Work

Prime farmland, previously unusable in times of high water, can now be used during the worst of floods to produce food and fiber



The Hannibal, Mo., Flood Control Project protected the city from Mississippi River flooding.

St. Louis Levee in 2001

Mississippi River Commission Today

- The MRC is still made up of the original 7 positions
- The president of the MRC is also the Commander of the MVD
- The districts inspect the levees twice annually
- Levee teams are comprised of: COE, FEMA, state agencies, customer, and contractor

Brigadier General Edwin J. Arnold, Jr. (right) heads the MRC

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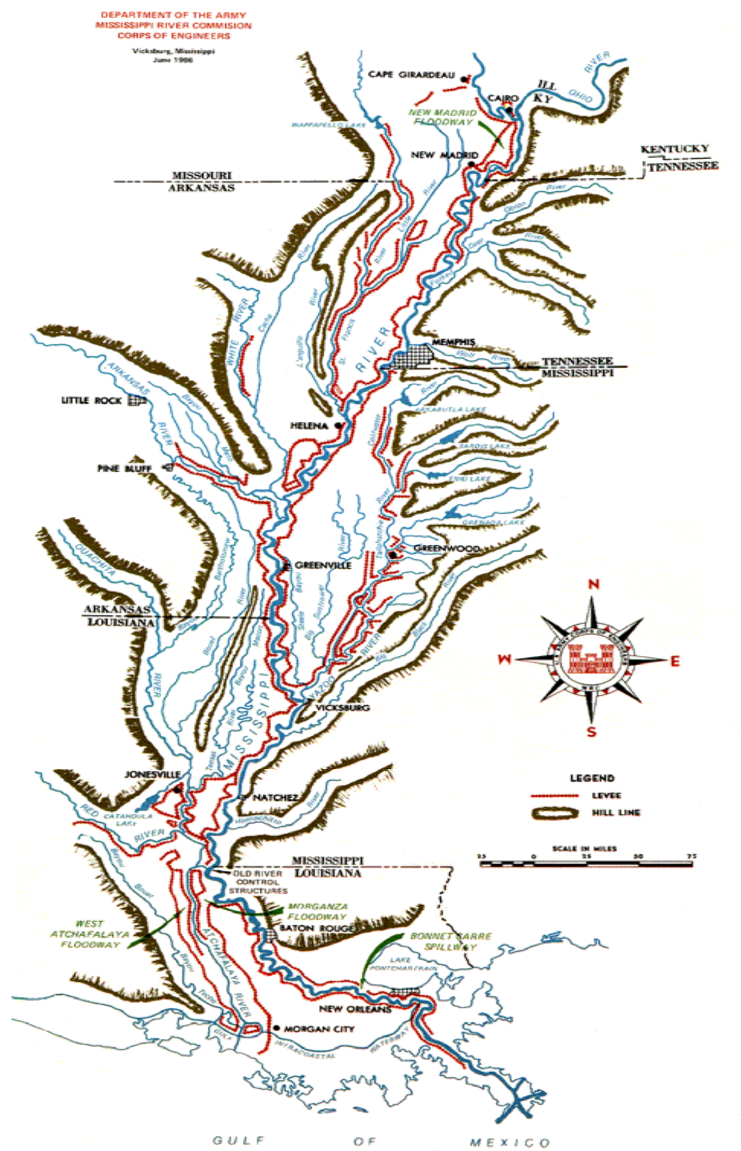
Present Day Levee System

- **The main stem levee system, comprised of levees, floodwalls, and various control structures, is 2,203 miles long. Some 1,607 miles lie along the Mississippi River itself and 596 miles lie along the south banks of the Arkansas and Red rivers and in the Atchafalaya Basin.**



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Example of Current Costs

Item	Description	Quantity	Unit	$/Unit	Amount
Levees					
West Lewiston Levee - Snake River Above Confluence					
1	Levee Excavation	2,200	yd^3	$2.50	$5,500
2	Levee Fill	29,000	yd^3	$10.00	$290,000
3	Bin Wall (Surface Area)	63,200	ft^2	$14.00	$884,800
4	Guardrail	7,400	ft	$20.00	$148,000
5	Pave Bike Path	52,000	ft^2	$2.00	$104,000
6	Landscaping		LS*	$100,000.00	$100,000
North Lewiston Levee					
1	Levee Excavation	14,000	yd^3	$2.50	$35,000
2	Levee Fill	120,000	yd^3	$10.00	$1,200,000
3	Bin Wall (Surface Area)	63,200	ft^2	$14.00	$884,800
4	Levee Riprap	6,500	yd^3	$40.00	$26,000
5	Guardrail	6,000	ft	$20.00	$120,000
West Lewiston Levee - Clearwater and East Lewiston Leve					
1	Levee Excavation	18,000	yd^3	$2.50	$45,000
2	Levee Fill	53,000	yd^3	$10.00	$530,000
3	Bin Wall (Surface Area)	200,000	ft^2	$14.00	$2,800,000
4	Guardrail	17,000	ft	$20.00	$340,000
Asotin City Levee					
1	Levee Excavation	16,800	yd^3	$2.00	$33,600
2	Levee Fill	80,800	yd^3	$10.00	$808,000
3	Riprap	4,770	yd^3	$40.00	$190,890
	Subtotal				$8,286,700
	Contingency - 20%				$1,657,340
	Total for Levees				**$9,944,040**

Table E-8-3
Construction Cost Estimate.
Schedule C: 4-Foot Levee Raise

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New Technology

- Geotube^{TM} technology developed under the COE Construction Productivity Research Program
- This concept minimizes environmental damage and reduces cost and time needed to construct Mississippi River flood protection levees.

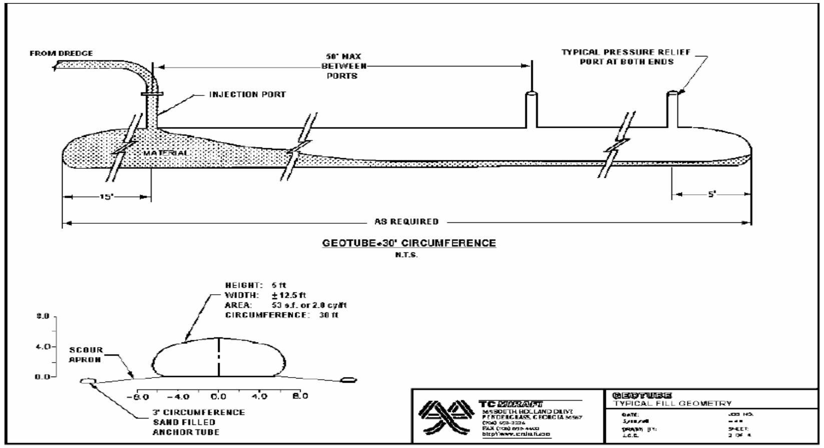

Figure 1. Standard Detail for Geotube^{TM} 30 ft Circumference

Figure 3. Photograph of Geotube^{TM} Dike with Dredged Fill behind Geotube^{TM} in the Netherlands

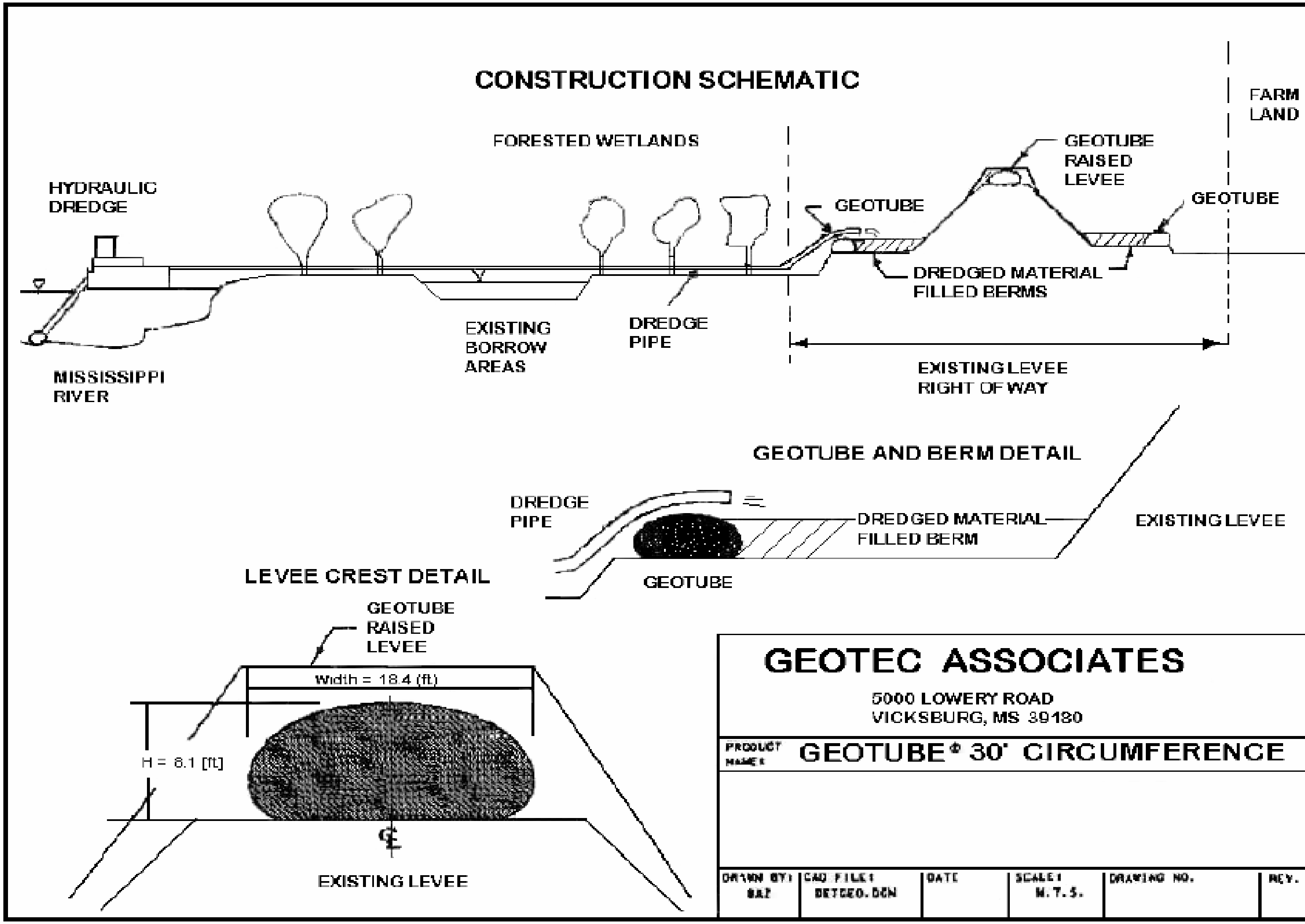

Figure 4. Profile View of Proposed Construction Schematic and Details for Dredge Filled Geotube™ and Berms for Raising Mississippi Levees

Geotube^{TM}

- Previous costs by the Corps of Engineer, Vicksburg District, per mile for raising 83 miles of levee over the past 23 years has been $2.8 million per mile. The estimated cost for future levee construction to the year 2029 (33 years) is estimated to be $3.2 million per mile for 220 miles of proposed levee or $698 million. This proposed construction method using geotubes is $1.5 million per mile for a savings of $368 million compared to conventional construction methods proposed by the Corps of Engineers.

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CONCLUSIONS

- The evolution of the Mississippi River system can be tied to costs, technology, politics, and oversight authority, but the number one factor is the river itself.
- The flow of the Mississippi River during times of flooding has been the single most important contributing factor to the changes in the levee system from the times of European settlers through the present.

REFERENCES - 1

- Addison, James D. The Mississippi River and Tributaries Project. 19 May 2004. New Orleans District, U.S. Army Corps of Engineers. 02 October 2004. http://www.mvn.usace.army.mil/pao/bro/misstrib.htm.
- Camillo, Charles A. and Matthew T. Pearcy. Upon Their Shoulders. 2004. Mississippi River Commission. 17 October 2004. http://www.mvd.usace.army.mil/MRC/Upon_There_Shoulders/index
- Clay, Floyd M. A Century on the Mississippi. Washington, D.C.: U.S. Government Printing Office, 1986.
- Department of the Army. Design and Construction of Levees. Washington, D.C.: U.S. Government Printing Office, 1978.
- Department of the Army. The Great Flood of 1993 Post-Flood Report. Washington, D.C.: U.S. Government Printing Office, 1994.
- Department of the Army. Improvement of the Lower Mississippi River and Tributaries. Washington, D.C.: U.S. Government Printing Office, 1972.
- Department of the Army. Mississippi River Engineers Report: Mississippi River and Tributaries Project. Washington, D.C.: U.S. Government Printing Office, 1964.
- Dobney, Fredrick J. River Engineers on the Middle Mississippi. Washington, D.C.: U.S. Government Printing Office.

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REFERENCES - 2

- Elliott, D. O. The Improvement of the Lower Mississippi River for Flood Control and Navigation. St. Louis, MO: M.R.C. Print, 1932.
- Flood Briefing. 2003. Rock Island District, U.S. Army Corps of Engineers. 12 October 2004. http://www.mvr.usace.army.mil.
- General Levee Information. 28 August 2004. Memphis District, U.S. Army Corps of Engineers. 14 October 2004. http://www.mvm.usace.army.mil.
- Have Flood Controls on the Mississippi River Been Successful? McDougal Littell, A Houghton Mifflin Company. 21 September 2004. http://www.classzone.com/books/earth_science/terc/content/investigations/es1308/es1308page02.cfm?chapter_no=investigation.
- Mark Twain's Mississippi River. Northern Illinois University. 7 October 2004. http://dig.lib.niu.edu/twain/images/hp-levee.html.
- Martin, Mark E. Baton Rouge: Levee Construction, Mississippi River. February 2003. Louisiana State university. 09 October 2004. http://www.lib.lsu.edu/special/exhibits/Lytle/A14.html.
- McCormick, Joe. A slide show on the Mississippi River and Tributaries Project. Mississippi Valley Division, U.S. Army Corps of Engineers. 05 November 04. http://www.mvd.usace.army.mil/MRC-History-Center/commission/Flood/projfld1.html.

REFERENCES - 3

- Mississippi Valley Division, Executive Office. 23 September 2002. Mississippi Valley Division, U.S. Army Corps of Engineers. 11 November 2004. http://www.mvd.usace.army.mil/Offices/eo/eo.html.
- Mills, Gary B. Of Men & Rivers. Washington, D.C.: U.S. Government Printing Office, 1978.
- Munger, Paul R., et.al. LMVD Potamology Study (T-1). Rolla, MO: University of Missouri – Rolla, 1976.
- New Mississippi River Levee Westbank Trail. 12 September 2002. Bertaut Sports. 27 October 2004. http://www.650motorcycles.com/91202ride.html.
- Phillips, Shawn. May 2002 Flood. Memphis District, U.S. Army Corps of Engineers. 14 October 2004. http://www.mvm.usace.army.mil/stjohns/images/graphics/
- Reuss, Martin. Designing the Bayous; The Control of Water in the Atchafalaya Basin. Washington, D.C.: U.S. Government Printing Office, 1998.
- Robinson, Michael C. The Mississippi River Commission; An American Epic. Washington, D.C.: U.S. Government Printing Office, 1989.

REFERENCES - 4

- Strauser, Claude N. Personal Interview. 12 June 2002 and 8 October 2004.
- Strauser, Claude N. E-mail Interview. 09 November 2004.
- Tweet, Roald. A History of the Rock Island District Corps of Engineers. Washington, D.C.: U.S. Government Printing Office, 1975.
- Tipton, Virgil. High and Mighty; The Flood of '93. Kansas City, MO: Andrews and McMeel, 1993.
- Vogel, Carole G. The Great Midwest Flood. New York, N.Y.: Little, Brown and Company, 1995.
- Wayman, Norbury L., Life on the River. New York, N.Y.: Crown Publishers, 1971.